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ABSTRACT

This publication, issued twice per year, includes proceedings from Two-Year College Chemistry Conferences and papers of special interest to the two-year college chemistry teacher. Relevant applications of chemistry are discussed, including the chemistry of flame retardance and photographic processes. Also discussed are topics related to the teaching of first-year general chemistry and second-year chemistry courses, such as organic chemistry and chemical instrumentation. Additional topics include individualized teaching methods in chemistry, chemical technology programs, and chemistry for the nonscience student. (MH)

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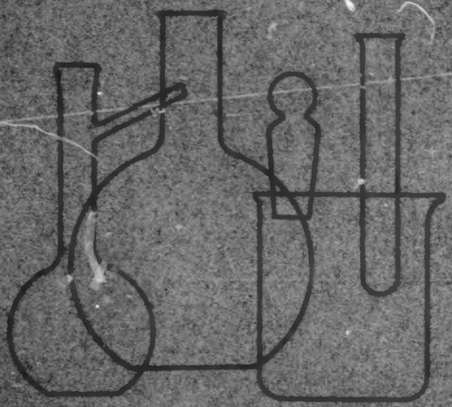

CHEMISTRY
IN THE
TWO-YEAR COLLEGE

VOLUME XI 1973

COMMITTEE ON CHEMISTRY IN THE TWO-YEAR COLLEGE
DIVISION OF CHEMICAL EDUCATION • AMERICAN CHEMICAL SOCIETY

SE 021 319

Foreword

Chemistry in the Two-Year College will soon be a current journal reflecting activities reported at meetings, which were held within the past six months. We see the journal filling an important role in Chemical Education Literature. At each of the five regional meetings, Chemistry teachers from that area present ideas which they are presently using. These may include curriculum design, teaching techniques, articulation, etc. Often our colleagues in the four year colleges and universities are struggling with the same types of problems and are asked to join us. Thus we are able to discover ideas from all over the United States and Canada. Some ideas may be in the formulative stage, others may be complete and comprehensive programs. We hope that these papers will give you motivation and serve as a spring board to try techniques which will improve your teaching. We hope that the papers presented at each conference will be of a high quality that will make stimulating reading for you.

To add to this concept of idea exchange, we will feature a page in the Journal called Innovative Images. This will be a feature which will allow you to submit ideas you are using and are willing to share with other chemistry teachers. The rules are:

1. Submit a description of what you have to share in 100 words or less to the Editor. Longer descriptions will NOT be considered.
2. Give your name and mailing address.
3. Each person who submits an idea agrees to acknowledge all correspondence from readers.
4. The Editors and/or the Editorial Board will decide which articles will be published. Their decision is final.

We hope to hear from many of you who may not have had an opportunity to present a paper at a conference.

You may note that a new method of identifying issues is now in use. This is the eleventh volume of the Journal to be published and the papers were presented in 1973. In the future we will use serial numbering with an identifying year.

Jay & Ellen Bardole
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Relevant Applications of Chemistry

The Chemistry of Polymer Burning and Flame Retardance

Arnold Factor
General Electric Research & Development Center
Schenectady, New York

Presented to the Concurrent Session, the Thirty Seventh Two-Year College Chemistry Conference, Monroe Community College, Rochester, N.Y., October 13, 1973.

INTRODUCTION

Polymer flammability is an extremely important subject for all of us. Most of the "things" we use are made of polymers: wood, paper, cotton, synthetic fabrics, plastics. How will these materials behave when exposed to a fire hazard? This question is one of increasing importance in the current direction of polymer and particularly, plastics* research. As shown in Figure 1, plastics are the fastest growing construction material in this country. Being modern man's most versatile and widely useful class of materials, plastics appear in almost every conceivable application. Many of these applications involve substantial fire hazard. For these cases, the plastics used must be formulated to minimize this risk. The chemistry underlying flame retarded formulations is the basic theme of this paper. In the first section, the theory of polymer burning is described, and based on this theory, the practice of polymer flame retardance is developed in the second section. The purpose of this paper is, of course, illustrative rather than inclusive and readers desiring more information should consult the literature.[1-4]

CANDLE-LIKE MODEL OF POLYMER BURNING

Currently it is believed with few exceptions that polymers burn in a manner similar to candles. Perhaps the most lucid description of the chemistry of candle burning is the classic series of Christmas lectures for young people presented at the Royal Institution (Great Britain) in 1860 by Michael Faraday entitled "The Chemical History of a Candle".[5] During these lectures, Faraday performed a key experiment demonstrating the presence of unburned volatile fuel within the burning mantle of a candle flame. As shown in Figure 2, he was able to tap a flammable "vapor" by placing a hollow glass tube into the flame and then ignite the "vapor" exiting the other end of the tube. In this way he demonstrated that the wax of the candle did not burn

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*In this paper the term "plastics" is used to describe the industrial material produced by blending a synthetic polymer or a mixture of polymers with the fillers, reinforcing agents, stabilizers and colorants required for its end use.

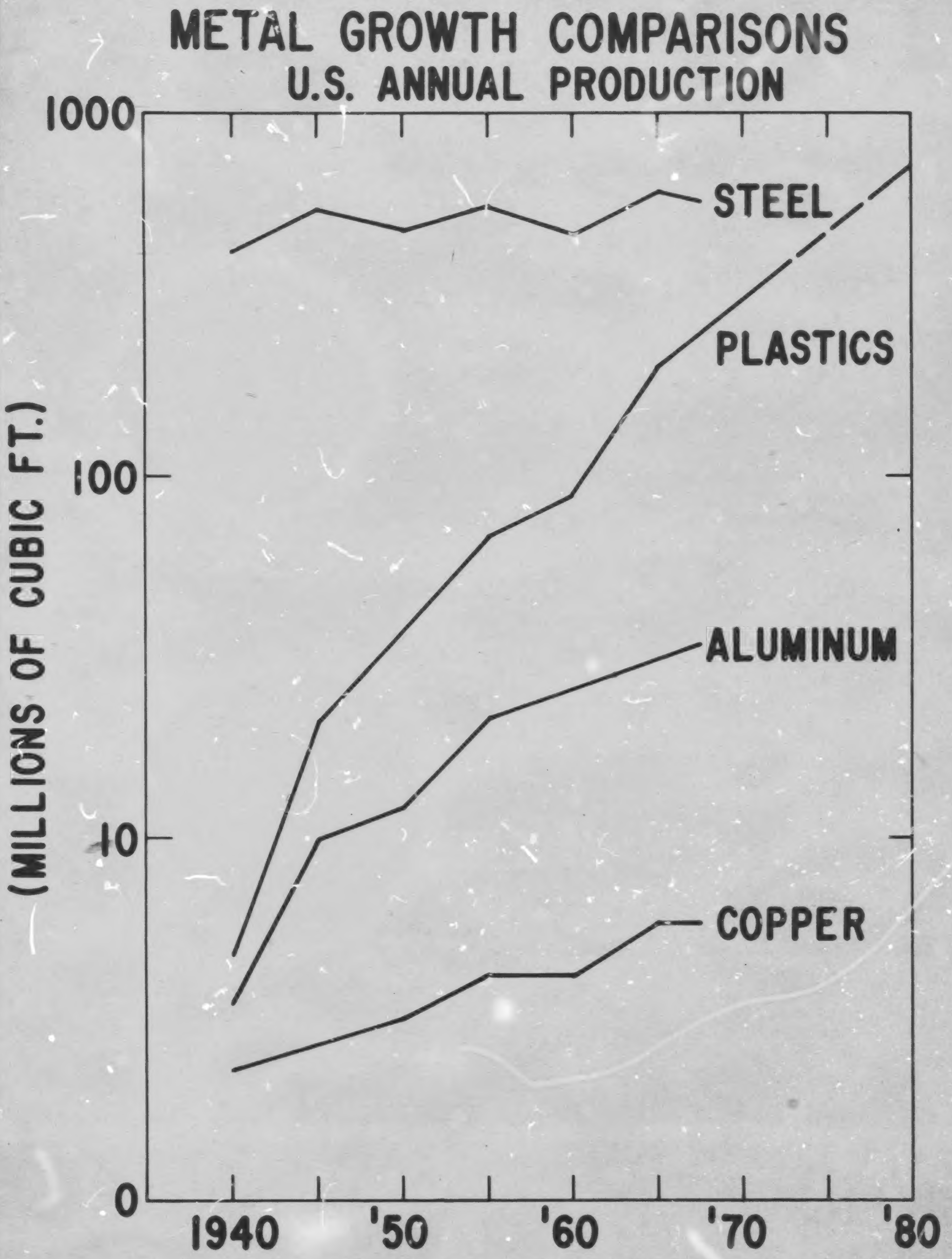


Fig. 1 PLASTICS GROWTH

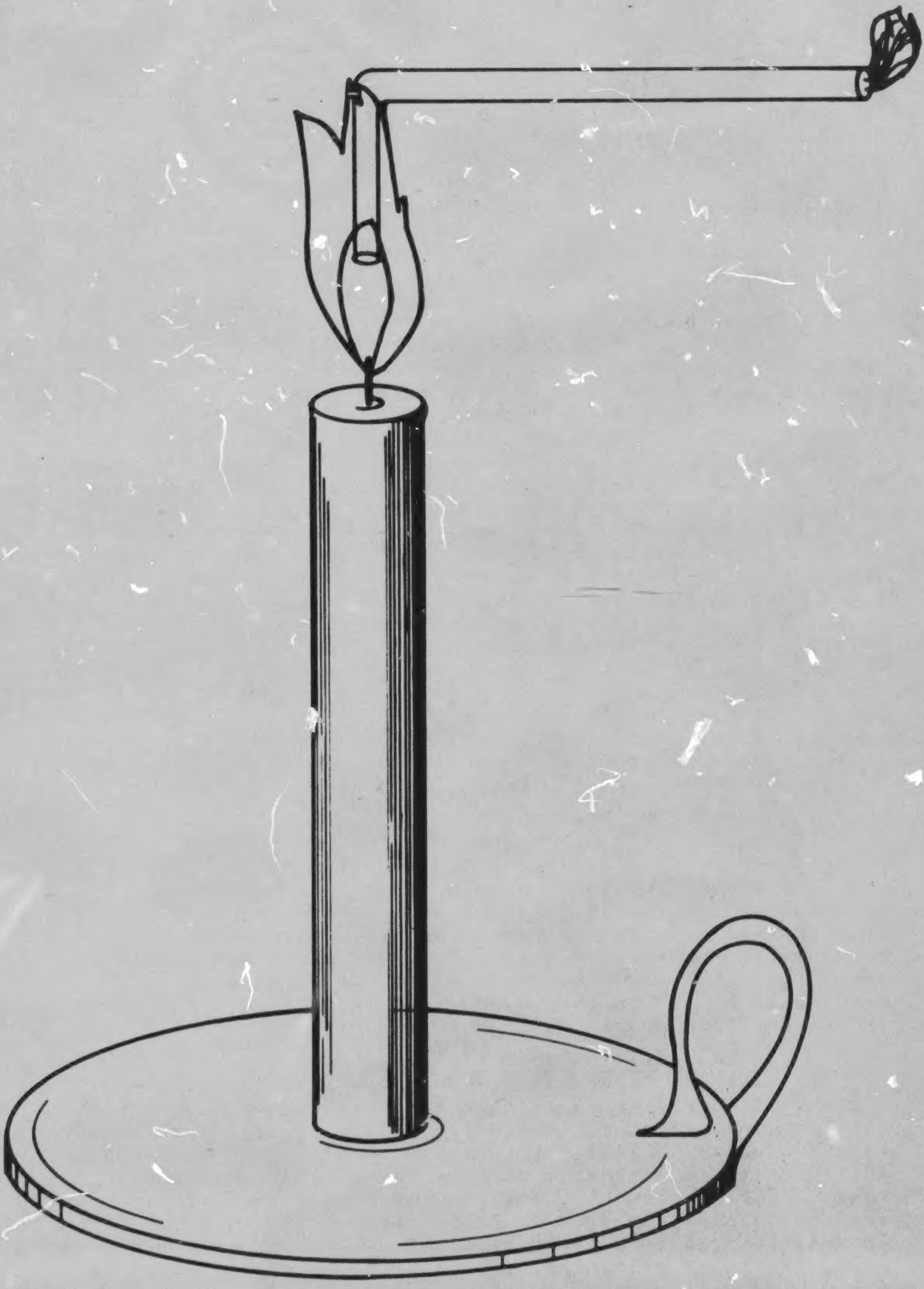


Fig. 2

FARADAY'S EXPERIMENT OF THE CANDLE FLAME directly, but was first converted to volatile fuel by the heat of the flame. In the study of polymer burning, modern scientists have borrowed from Faraday's lecture experiment. However, instead of burning the flammable "vapor" tapped from within a polymer flame, they pass the gas into a mass spectrometer and obtain a detailed chemical analysis of the flame. The results of such a study on the burning of polymethyl methacrylate, performed at our laboratories, is shown in Figure 3.[6a] This study indicates that at the high surface temperatures produced by the flame, the polymer "unzips" to its basic building block, methyl methacrylate. As this diffuses toward the flame front, it in turn is completely broken down to lower molecular weight fuel gases, i.e., CO, H_2 and C_2 hydrocarbons. At the flame front these gases react with molecular oxygen to produce the flame. Thus, as illustrated in Figure 4, the candle-like model of polymer burning consists of a closed cycle in which external heat causes the polymer to decompose in the condensed phase, producing volatile fuel gases which react with oxygen in the vapor phase as a flame which in turn produced more heat. In this model, the only role played by oxygen is as one of the reactants in the flame reaction. As is the case in most theoretical models, the above picture is somewhat over-simplified. Currently, as summarized in Figure 5, it is thought that only polymers which readily "unzip" to fuel gases, such as polymethyl methacrylate (PMMA) or polyoxymethylene, burn by the above mechanism. In fact, the majority of polymers are presently thought to burn by a mechanism in which surface oxidation plays an important role in the production of the fuel gases. Finally, at the other extreme, there are a few materials such as polytetrafluoroethylene (PTFE) in which combustion hardly involves a vapor phase oxidation at all, but is almost totally a surface reaction.[6a]

THEORY OF FLAME RETARDANCE

The basic ingredients for sustained combustion are fuel, oxygen, and heat. Disruption of this classic triangle is the key to fire suppression. In plastics, this is generally achieved by incorporating flame retarding elements or compounds into the starting polymer. In the preceding section, polymer burning was shown to involve both vapor phase and condensed phase reactions. Correspondingly, analysis of the mechanism of flame retardance has shown that some flame inhibitors operate primarily in the vapor phase and others primarily in the condensed phase.

Vapor Phase Flame Inhibition

In order to understand the mechanism of vapor phase inhibition, it is necessary to look more closely at flame reactions. The lean, pre-mixed methane-oxygen flame is well understood and can be used as a model for the more complex polymer flames.[6b,7] As indicated in Figure 6, methane combustion is a complex free-radical chain reaction consisting of propagation, chain branching and termination steps. It is interesting that for a reaction in which oxygen is a major reactant, oxygen is only found in one step, the major branching step. In the branching step, two

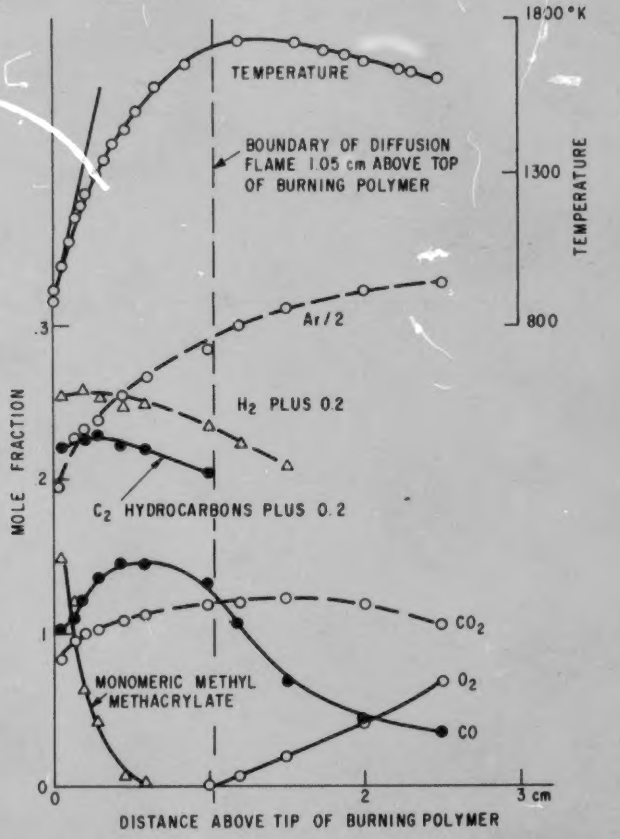


Fig. 3

Gas composition and temerature along the central axis above a polymethyl methacrylate rod, 0.36 cm^2 cross section, burning at 5 cm of mercury pressure in argon-oxygen, 20% O_2. Distances are measured from the burning tip, and the dashed line at 1.05 cm shows the position of the visible diffusion flame. For clarity, H_2 and C_2 hydrocarbons are displaced 0.2 upwards.

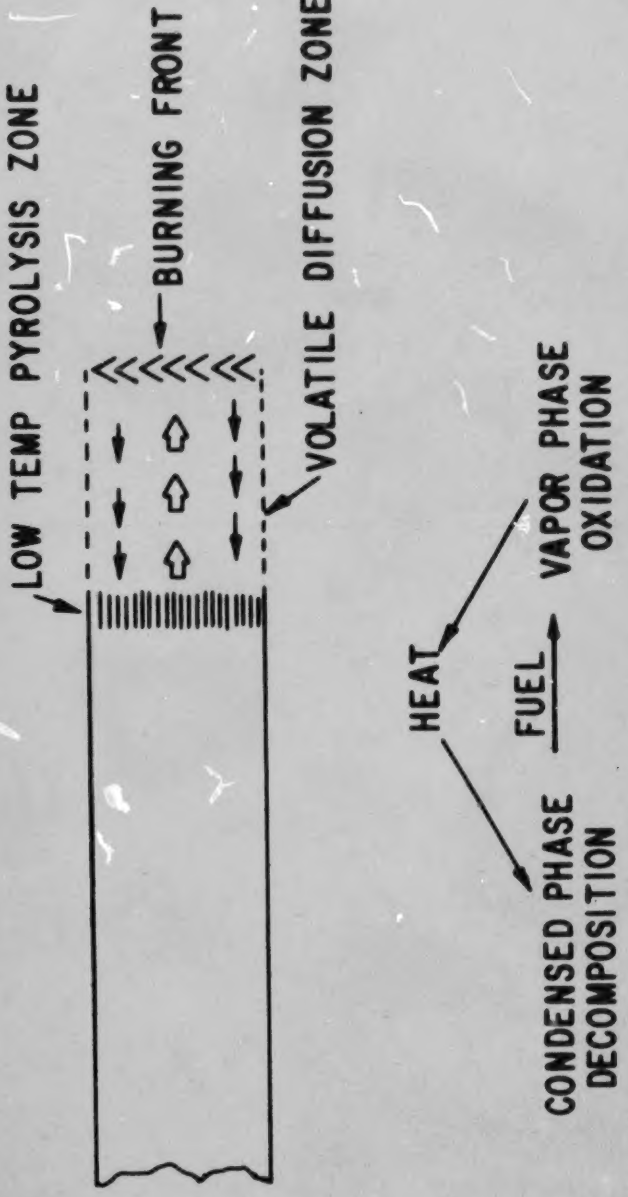


Fig. 4

CANDLE-LIKE MODEL OF POLYMER BURNING

POLYMER BURNING

CANDLE-LIKE MODEL

- i O_2 UNIMPORTANT FOR FUEL PRODUCTION
  "UNZIPPING" POLYMERS - PMMA, $\left[CH_2O \right]_n$
- ii O_2 CATALYSIS OF FUEL PRODUCTION
  MAJORITY OF POLYMERS

DIRECT SURFACE COMBUSTION

LIMITED CASES - PTFE, CARBON(ELECTRODE)

Fig. 5

MECHANISM OF POLYMER BURNING

MECHANISM OF METHANE COMBUSTION

PROPAGATION

$$CH_4 + HO\cdot \longrightarrow CH_3\cdot + H_2O \tag{1}$$

$$CH_4 + H\cdot \longrightarrow CH_3\cdot + H_2 \tag{2}$$

$$CH_3\cdot + O\cdot \longrightarrow CH_2O + H\cdot \tag{3}$$

$$CH_2O + CH_3\cdot \longrightarrow CHO\cdot + CH_4 \tag{4}$$

$$CH_2O + HO\cdot \longrightarrow CHO\cdot + H_2O \tag{5}$$

$$CH_2O + H\cdot \longrightarrow CHO\cdot + H_2 \tag{6}$$

$$CH_2O + O\cdot \longrightarrow CHO\cdot + HO\cdot \tag{7}$$

$$CHO\cdot \longrightarrow CO + H\cdot \tag{8}$$

$$CO + HO\cdot \longrightarrow CO_2 + H\cdot \tag{9}$$

CHAIN BRANCHING

$$H\cdot + O_2 \longrightarrow HO\cdot + O\cdot \tag{10}$$

TERMINATION

$$H\cdot + R\cdot + M \longrightarrow RH + M^{*} \tag{11}$$

Fig. 6

MECHANISM OF METHANE COMBUSTION

chain-carrying radicals are produced for every one consumed and accounts for the explosive nature of burning. The main chain-carrying radicals in the propagation steps are the hydrogen atom and hydroxy radical. Inspection of this mechanism predicts that any material which either lowers the concentration of these chain-carrying radicals or increases the rate of termination will inhibit the flame reaction. Indeed, this is thought to be the mechanism by which vapor phase flame inhibitors work. For example, the presence of HBr, produced by the pyrolysis of a bromine-containing organic material in the polymer, acts as a radical scavenger and replaces less reactive bromine atoms for active chain carriers, which, as shown in Figure 7, inhibits both the propagation and branching steps. A second class of vapor phase inhibitors is thought to operate by catalyzing the termination step. For example, sodium bicarbonate has been found to be a much more effective fire extinguisher than predicted by the liberation of carbon dioxide alone.[4] It is thought that the sodium atom produced from the sodium bicarbonates is the active agent, catalyzing the combination of chain-carrying radicals as shown in Figure 8. Other flame inhibiting agents which are thought to act by this mechanism are volatile metal compounds such as iron pentacarbonyl, ferrocene, tetraethyl lead, antimony trihalide (produced *in situ* by reaction of Sb_2O_3 with organohalides in the pyrolysis zone[8]) and several organophosphorous compounds.[9]

Condensed Phase Flame Inhibition

There are two important modes of solid phase flame inhibition, cooling and formation of a char barrier. In Figure 9 is outlined several cooling modes in polymer burning. The first, the filler effect, occurs when the burning polymer contains a pigment or filler which conducts heat better than the polymer. In these cases, the filler conducts heat away from the hot region more effectively than the unfilled polymer and is correspondingly more difficult to burn. Unfortunately, the filler loadings required to significantly effect polymer flammability are usually high and thus of limited use.

A second cooling mechanism is dripping. Materials which drip easily during burning are more difficult to burn. For example, because of its high dripping tendency, ordinary candles will not burn without a wick. Again, this is because heat is removed from the flaming area. Dripping, however, is considered to be a hazard in itself by contributing to the spreading of a fire and therefore also is of limited use.

The most important cooling mode used in condensed phase flame inhibition is the use of materials which decompose endothermically in the pyrolysis zone of the burning polymer. For example, as shown in Figure 9, polyvinyl alcohol is thought to be less flammable than the isomeric polyethylene oxide because of the former material's ability to endothermically form water. Also, hydrated alumina, which is a commercial flame inhibitor, is far more effective than anhydrous alumina for the same reason.

VAPOR PHASE FLAME INHIBITION

RADICAL SCAVENGING

REPLACE ACTIVE CHAIN CARRIERS

$$H\bullet + HBr \longrightarrow H_2 + Br\bullet$$

$$HO\bullet + HBr \longrightarrow H_2O + Br\bullet$$

SLOW BRANCHING STEP

$$H\bullet + O_2 \longrightarrow HO\bullet + O\bullet$$

Fig. 7

VAPOR PHASE FLAME INHIBITION - RADICAL SCAVENGING

VAPOR PHASE FLAME INHIBITION

RADICAL RECOMBINATION CATALYSTS

$$\begin{array}{l} \mathrm{HO}\bullet + \mathrm{Na}\bullet \longrightarrow \mathrm{NaOH} \\ \mathrm{NaOH} + \mathrm{H}\bullet \longrightarrow \mathrm{H_2O} + \mathrm{Na}\bullet \\ \hline \mathrm{HO}\bullet + \mathrm{H}\bullet \xrightarrow{\mathrm{CATALYST}} \mathrm{H_2O} \end{array}$$

EXAMPLES: $NaHCO_3$, $Fe(CO)_5$, $PbEt_4$, Sb_2O_3-
HALOGEN, PHOSPHOROUS COMPOUNDS (?),
FERROCENE (?)

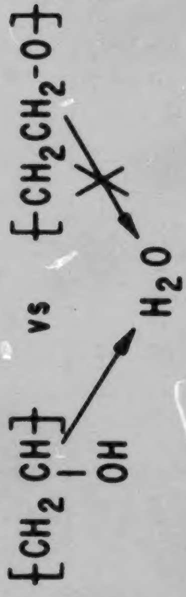
Fig. 8

VAPOR PHASE FLAME INHIBITION - RADICAL RECOMBUSTION CATALYSTS

CONDENSED PHASE FLAME INHIBITION

COOLING MECHANISMS

- i FILLER EFFECTS
- ii DRIPPING
- iii ENDOTHERMIC REACTIONS



$[CH_2CH(OH)]$ vs $[CH_2CH_2\text{-}O]$

H_2O

$Al_2O_3 \cdot 3H_2O$ vs Al_2O_3

Fig. 9

CONDENSED PHASE FLAME INHIBITION - COOLING MECHANISM

Often water forming endothermic reactions can be promoted by the addition of a suitable catalyst. For example, the primary combustion step in the burning of cellulosic materials is the high temperature production of volatile levoglucosan, as illustrated in Figure 10. The addition of certain phosphorous or boron compounds has been found to catalyze the endothermic water elimination reaction which diverts the levoglucosan reaction, cools the pyrolysis zone, and promotes charring. This is the key mechanism by which flame resistant cotton fabrics are presently commercially produced.

Finally, as indicated for the burning of cellulose, char formation is an important mode of flame inhibition. The formation of a tough, thermally stable char acts as a barrier which both insulates the unreacted substrate from the heat of the flame, and also serves to contain volatile fuels from feeding the flame. Also, as more of the pyrolysis reaction is diverted toward char formation, less gaseous fuel is formed. The mechanism of char formation is poorly understood. Generally, it is an inherent property of certain polymers, particularly those with a high aromatic content. Also, as illustrated above for cellulose, the presence of certain catalysts often can be used to promote and enhance the quality of the char.

MECHANISM OF SMOKE FORMATION

Smoke and toxic gas formation can be as much a hazard to life as polymer burning and should be discussed. The mechanism of smoke formation in burning polymers is only partially understood. Probe studies of various hydrocarbon flames[6c,8] indicate that smoke is formed by radical reactions involving the formation and condensation of acetylene. At first, soot spheres 40Å in diameter of the empirical formula CH are formed. Particles smaller than 40Å are oxidized by hydroxyl radicals and do not survive. As these particles move from the flame, they grow to an average diameter of 100Å and are oxidized to the empirical formula C_2H and ultimately form visible soot. It is of interest that most of the light emitted from a burning candle or polymer is due to the presence of these hot incandescent carbon particles in the flame.[5] In the case of materials which produce benzene on burning, more smoke is produced, presumably in a mechanism involving the radical condensation of both benzene and acetylene. These reactions are summarized in Figure 11.

Presently no practical means have been found to decrease the smoke generation in burning polymers, although materials such as PTFE and certain polysiloxanes and polysulfones have been found to be inherently low smoking materials. To make matters worse, many flame retardants, especially those operating by a vapor phase mechanism, have been found to increase the production of smoke because they decrease the rate of the early smoke-consuming hydroxyl radical reaction.

Toxic gas formation, because of its difficulty to assess, has received little attention until recently. The yield and type of toxic gases formed on burning vary greatly according to the type of material burned and the conditions of burning.

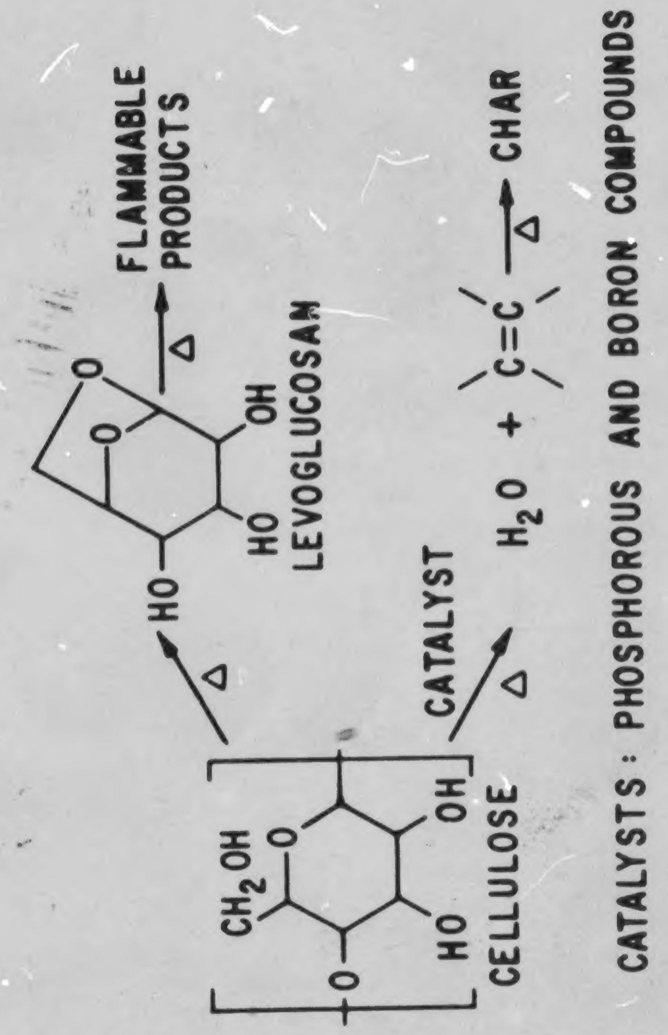


Fig. 10

MECHANISM OF CELLULOSE BURNING

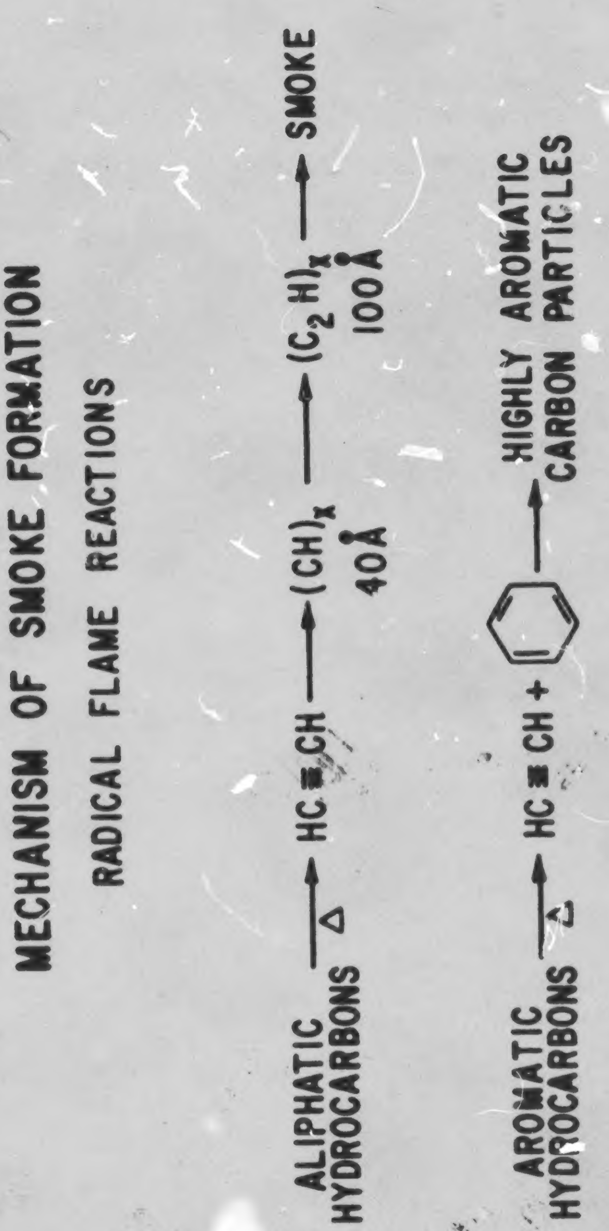


Fig. 11

MECHANISM OF SMOKE FORMATION

Typical toxic gases produced in burning plastics are CO, CO_2, organic acids, aldehydes, halogen acids, HCN, H_2S, SO_2, etc. The actual hazard of these various materials in a real fire situation is presently the subject of active research in many laboratories.[11]

SUMMARY

This paper describes the current theories on the mechanism of polymer burning and flame retardance. Much is still unknown. Many topics such as flammability testing and inhibitor synergism were not considered within the scope of this paper, but can be found in the literature.[1-4] Currently material flammability is one of the most rapidly growing areas of research in this country. In the coming years many new inroads in our understanding and an increase in the flame safety of materials can be expected.

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The Chemistry of Photographic Processes

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Presented to the symposium on Relevant Illustrations and Applications of Chemical Principles, the Thirty Seventh Two-Year College Chemistry Conference, Monroe Community College, Rochester, N.Y., October 13, 1973.

Man's behavior is controlled through his brain and nervous system, a neurological computer with an ever-changing program. This computer accepts five types of data input. It is generally agreed that the visual input is most important. Scientists have estimated that up to 90% of the data to which man reacts reaches him through his sense of vision.

The theme of today's program has to do with relevance in today's world. Certainly an important aspect of this world is man's relationships with man. Much in these relationships is centered about communication between men. Certainly then, data transfer between men is relevant.

Based on our 90% estimate, a visual method of transfer would be best. The tremendous upsurge in the use of motion pictures, slides, film strips is evidence of general acceptance of the idea that visual communication is efficient communication.

Let me turn on this illuminator and stimulate your retina with data. What do you see? You see a young couple on the be beach enjoying a day of sailing under a sunny sky. This is really information. That is, light from this illuminator struck your retina; this is the data input. Your brain analyzed these data and the result is information about the couple enjoying sailing.

Now suppose you wanted someone else, in another time and place, to have this same information. What is the problem and how can it be solved? The problem is how to present the data your retina is receiving to the retina of the other observer.

Let us examine the data input to your retina more carefully. Data input must be in a form which can be accepted. According to the Young-HelmHoltz theory of color vision, we have three types of color receptors, and only three need be postulated to explain most of the facts of color vision. One of the color receptors is sensitive in the region of the spectrum roughly between 600 and 700 nanometers. Here is a filter which transmits in that region and I'll place it over this second illuminator. You have an overall color response you call red. Let me place a similar filter over our original subject. Now you do not see a uniform red field, but varying amounts, from full red to black. These differences are displayed on your retina by the lens of your eye. This might be termed the red data input. The fact that you see swimmers and a boat is due to interpretation of the data by your brain to generate information. The data input is varying amounts of 600 to 700 nanometer energy displayed on different parts of your retina, red data input.

We have two other color receptors. One sensitive in the region roughly between 500 to 600 nanometers, and one sensitive in the region roughly between 400 and 500 nanometers. Let us go through the same procedure with these two to further analyze our original into green data input and blue data input.

If then, as postulated, we have three and only three color receptors, each sensitive to approximately one third of the visible spectrum, what is our problem if we want someone at another time and place to have the same information we have. We must present simultaneously to his retina the same three sets of data that you have in seeing this original. How can this be done?

Obviously, I am going to suggest a photographic solution to the problem. So that we all begin at the same place, I am going to define photography and go from there.

Photography is the art and science of recording on a light-sensitive material a two-dimensional representation of a two- or three-dimensional aggregate of objects.

What is the light-sensitive element used in photographic systems? I am sure you have all run a chloride analysis and watched your coagulated precipitate turn dark. Well, this silver chloride is one of the light-sensitive compounds used. Light energy is absorbed by the crystal and some of the silver ions in the crystal are reduced to metallic silver. That is, a change in the crystal is brought about by the action of light - it is light sensitive.

In the time allotted to me I can only touch upon the chemistry involved in the photographic system. What I hope to do is demonstrate to you how this chemistry is relevant to visual communication in today's world.

A black-and-white photographic material is, in simplest terms, a dispersion of silver halide crystals in gelatin coated on a suitable support. The basic reaction is as shown in this slide. Let me demonstrate this to you. I will take some KCl and gelatin dissolved in water and add, with stirring, some $AgNO_3$. I will divide the resulting material into two portions. Both of these have, of course, been exposed to room light and some of the silver ions have been reduced to silver metal, that is, the salt is light sensitive. Now for the black-and-white magic of it all. If I add to one of these a solution of mild reducing agent, the reaction shown in the next slide occurs at the site of the light produced silver metal specks. This is the black part. The silver halide grains are reduced to metallic silver with an amplification effect of about a billion to one over the other sample which is still reacting to light. This is the reason for the tremendous usefulness of the silver halides.

In order for a black-and-white material to be permanent, it is necessary to remove the still light-sensitive salts from the coating, or in time they will turn black by the continuing action of light thus eliminating the differences between light struck and non-light struck areas. To do this we complex the very insoluble silver halides in a sodium thiosulphate solution. I'll add such a solution to this second sample. This is the white part. So now we have black and clear samples.

Let us see how this might be used to solve our problem. Suppose we imaged the red light distribution coming from this original scene through a lens system onto a red sensitive silver halide coating. If we then treated it in a suitable solution of reducing agent, we would get metallic silver where it was struck by light. Let's look at the original and the photographic reproduction, each through a red filter. We see the reproduction is opposite in sense to the original, that is a negative. If we took this photographic negative and exposed another piece of material to it, we then would get, after processing, a negative of a negative, or a positive. If we look at the original and the silver positive record of the original, both through red filters, we see they both have the same red light distribution. We have what could be used as a red data input.

If we image the green light distribution onto a green sensitive material, we can reproduce the analagous green light distribution in the same way. We can also do the same with the blue light distribution.

We have recorded the red, green, and blue light distributions coming from the original, on appropriately sensitive silver halide materials, as you can see.

The red, green, and blue distribution data are coming to your retina simultaneously from this original subject. To do the same with these three records, we will have to superimpose them. That's what is done in the manufacture of a color film such as ektachrome; three silver halide layers, each sensitive to one region of the spectrum, red, green, or blue, are coated on the same support. If we simulate this condition by superimposing these three records on one illuminator, what do we get?

Obviously, this won't do. It is because the metallic silver produced as separate records of red, green, or blue are nonselective absorbers. That is, silver absorbs uniformly through the spectrum. Thus a silver image produced as a function of red light will hold back or absorb red light, which is what we need for a red data input, but unfortunately it will also absorb green light and therefore interfere with the green light data input. Similarly for the other records.

What is needed then, in order to present to an observer the red, green, and blue light distribution data simultaneously, are materials which will absorb in one region of the spectrum only; a red absorber, a green absorber, and a blue absorber.

These then, by definition, will be colorants, and their hue names are cyan, magenta, and yellow. Cyan absorbs red, but transmits blue and green. Magenta absorbs green, but transmits blue and red. Yellow absorbs blue, but transmits green and red, as I demonstrate on the illuminator.

In place of the red light silver record, we need a cyan colorant in place of the silver. We need a magenta for the green, and a yellow for the blue. This is accomplished by using, in the jargon of the trade, dye coupling development. If we use, as shown in this slide, a paraphenylene diamine type reducing agent to react with exposed silver halide, we will produce, as a function of exposure, a proportional amount of oxidized developer. This is not a reaction product to be removed as in black-and-white development, but is used to react with another compound, referred to as a coupler to produce a dye. An appropriate coupler can be coated in each layer so a cyan is produced in red sensitive layer, a magenta is produced in green sensitive layer, and a yellow is produced in blue sensitive layer.

I can simulate this on each illuminator. Now we have a silver and a dye image in each layer, but as you recall we do not want the silver image. These are removed in color film processing by bleaching and fixing. The bleach is usually a solution of potassium ferricyanide and potassium bromide. The ferricyanide oxidizes the silver metal to the ion which reacts with bromide ion with precipitation in the coating of AgBr. This AgBr is removed later in a fixing bath. You then have left in your film structure three dyes. One is a red light controller which gives the red data input. One is a green light controller giving the green data input, and one is a blue light controller giving the blue data input.

You see all three data inputs together when viewing the original. If these three dyes are in fact superimposed, as they are in a color film reproduction, we will be able to present to another observer, in another place and another time, the same three data inputs.

The Importance of Relevancy

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Presented at the symposium on Relevant Illustrations and Applications of Chemical Principles, the Thirty Seventh Two-Year College Chemistry Conference, Monroe Community College, Rochester, N.Y., October 12, 1973.

Yes, certainly. But relelvant to what, to whom, and for what purpose?

The only way I see to pursue these questions is to start with the classical separation of two problems,

1. What should be the subject matter?
2. What should be the method, the approach?

It may be that we should not be so quick to make this separation. We do, after all, as students in education courses, complain about the separation, and those of us who never had the courses derive much security from the complaints. But when we try to talk about relevancy or other issues we seem to be forced toward the separation.

For the present discussion the separation of subject and method makes it easy to dig in. Let us start with "method", which is as easy to deal with as learning French, and as hard to really deal with as really learning French. It seems to me that there are at least three distinct methods in our approach to formal education. One method is to try to get what is in my note book into the student's note book with a maximum involvement of brains at both ends, accepting a subject matter selected ahead of time by me or other authorities. Today this sounds horrible, but we have to admit that it did produce no less than you and me. And looking back I do see a mix of both good and bad learning situations based on this approach (based on any approach). Maybe it is expecting too much to try to identify a best method. In any case, for this approach there does not seem to be anything to say about relevancy except in connection with the subject matter.

There is a second approach which tries to be more subtle, using Platonic games. Given a selected subject matter, do not go at it directly, for there is no way to teach straight, but try to nudge the student to withdraw certain ideas from his bank of ideas and synthesize his own version of what is to be learned. Then judge the student by how quickly his banker responds, and how closely his version corresponds. Tell him not to memorize, for that by-passes his banker. We can't put new ideas into his already overstuffed bank but we can influence him to be creative in his withdrawals and accurate in his syntheses.

This second approach clearly calls for concern about relevancy. The teacher has to be clever enough to produce inputs for the student which will relate to his mental situation and also relate to the teacher's goal. Here, I think "relevancy" means "cleverness of teaching" and it is very important.

Let us refer to a third approach in which we go all out to call for the student's outputs. To find him where he really "is" and to give him a larger role in determining where he is going. This approach seems to go against the evolutionary interpretation of education (that the young animals must learn the accumulated lessons of the elders in order to be wise about survival, security, and success) but it could be what is called for to open up new dimensions of a new humanity. Who knows? The trouble with this approach as a topic in our discussion is that it is so difficult to get a handle on it. It reeks with relevancy of some type, but what type is that and how should it be controlled?

We could say, at this point, that different approaches are needed for different situations, and let it go at that. I am not so sure, however, that we can dispose of the question so quickly. I have noticed how a fellow teacher who uses a loose approach in an English literature course is able to bring successfully the same approach to a course on scientific literature. I expected him to be more rigid about what the students should look for, but he spent most of his time trying to get students really interested in really looking for anything. Most of them became interested and really took off becoming experts on some new topic. Topics were proposed by students and warped by the instructor. Relevance in this case was not relevance to current events or to the teacher's plan, but to the student's future interest. There was a little lecturing, a little nudging, a little freedom, but mainly persistent encouragement to try something that might become interesting. The older I get the more I think we should always be trying to get the student to come out toward us even if we do have to determine the direction. Instead of striving for relevance in our attempt to get information into the student's bank, maybe we should try to get the student to move out and look for relevance himself.

Generally it is difficult to find sweeping conclusions about relevancy in connection with methods. There is one specific area however, that calls for sweep, the area of visual aids. All of us have seen how much the aids can help in the nudging process. But we have also seen how much they can interfere when they are not relevant in the sense of being consistent with other inputs. Sometimes we are guided more by what aids are available than by what aids are called for, and the subject matter becomes confusing. The student panic is just below the surface, and if we scratch, we are puzzled. It is clear that relevancy is very important in connection with the use of aids; the aids must be "relevant" in the sense of being consistent with the goals of the subject matter and the psychological preparation of the student.

Usually when we talk about relevancy we are thinking about subject matter. We could mean something like one of the following:

1. Related to the life and outside interests of the student.
2. Related to modern situations as opposed to classical ones.
3. Related to future needs of the student, especially occupational.
4. Related to the truly important problems of mankind.
5. Meaningful in the sense of being helpful in the nudging process, i.e., clarifying or integrating or orienting other subject matter.

On the question of the importance of relating subject matter to the outside interests of students, I think we probably agree that this should be done a lot where the relation can be meaningful, a little where it can be a breather or an alarm clock, and hardly ever when there is no reason except to be rated high on relevancy.

On the question of relating subject matter to real situations in the modern world, it seems to me that we can err in both directions very easily. The surface of current events, recent data, modern technologies is not much help when we are trying to develop understanding of principles. We can do more to deepen our understanding in some directions by going back to earlier, often more profound thought. All of the descriptive examples in the modern chemical world will not help us to understand or explain why we are doing what we are doing as much as the history of thought, or at least the history of the subject. Complex examples can be very helpful if we are clever, but they are not as nudging as simple examples which stress motivation. At the same time our preoccupation with old stuff, however justifiable on some grounds, does gradually instill an obstacle to creativity and an insecurity about real situations. And certainly there is no logical reason to generally avoid modern ideas and technologies. In many cases the modern thing could be excellent education for the creative present, the occupational future, and the perspectives of the student. It seems to me that we have a large challenge in decisions about the relevancy of modern situations in connection with subject matter.

The occupational future of the student is certainly very important, but it is also a very tricky problem to deal with. It is hard to know what is really going to be helpful at a later time. We have a lot of thumb-rules to justify ignoring this problem, but it may be true that we should look for more relevancy in this area. My feeling is that we should acknowledge the uncertainty and give it more thought. Questionnaires to alumni bring back the damndest things, but maybe somebody should push that kind of study.

The truly important problems of mankind are certainly more important than learning how to solve equilibrium problems, but it does not follow, I think, that we should try to be "relevant" in this area. We should, of course, if the issue is supportive or clearly dependent or something like that, but the deliberate separation of educational activities, especially in institutions deliberately designed to make that separation, is a first requirement for bits of educational progress. The question here is not so much the importance of relevancy as the relevance of importancy, and I think the degree of importancy can be be constant in time; it must depend severely on long-range plans and current activities.

One of the most important opportunities for increased relevancy is in the area of improved inter-relations within the subject matter. What could be more relevant to the learner than an aid to learning? (It may be that we should refer to this kind of boost as increase in "meaningfulness" rather than an increase in "relevancy".) To be able to bring in something which helps to clarify or unify or orient, that may be the question. Maybe we should spend more time looking for ways to explain why we are doing what we are doing, where it really comes from, and where it really goes. And after that, repeated many times in different ways, come down on the details with more analogies, however bad and needful of patching up. It seems to me that the hardest thing for the beginning college student is why he suddenly does not have to know everything in a (hopeless) chapter, why he is doing what he thought was physics in a chemistry course, and where it is all headed. After that it might be a search for the gist of the subject, and how the different parts are interrelated. After that it might be what he has to know for the next test, and after that, he can do the arithmetic. The things that confuse may be our precisions and our sometimes irrelevant (to him) and sudden media aids. Relevance in tight situations might boil down to the clarity of the subject matter rather than the relation of the subject matter to the future, the world, or non-academic interests.

These rambling comments hardly add up to anything but they give a chance to point to two possible efforts for becoming more relevant in our teaching. One is to try to understand more about the origin and inter-relations of our own subject matter. That is hard to do and harder to share. The other is to become more familiar with modern applications of our science. Not to merely pick up terms here and there, as I am accustomed to doing, but to reach for some in-depth appreciation for the inner-workings of our technologies, and for some better overviews of the whole technological situation of our day. Then our attention to the world can become an integral part of a uniformly relevant subject matter. I am grateful for the opportunity we have today to hear from experts in some areas of modern technology. This may be the kind of input we need most for increasing the relevance of subject matter.

Articulation

They Came, They Saw, They Returned

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Presented to a Concurrent Session, the Thirty Fourth Two-Year College Chemistry Conference, Cuyahoga Community College, Cleveland, Ohio, May 11-12, 1973.

High school students come to a college campus, interact with the people there, and do an interesting experiment using instrumentation not normally available to high school laboratories. High School Laboratory Day may benefit everyone. It helps the high school teachers motivate their students, it helps the high school student learn, and it helps the colleges acquaint themselves with prospective students.

It is the responsibility of both the college and the high school to help their students bridge the interface which exists between the institutions. Ideally the concern in both institutions will be the same, teaching the student subject matter and how to deal with new and unknown situations - that is, how to deal with the real world. No single technique is the answer for helping the student attain his goals, but High School Laboratory Day is a program which makes a positive contribution toward this goal.

Our High School Laboratory Day is at the end of an evolutionary line, which began with a High School Night. We invited the high school faculty and students for an evening meal, and they toured our laboratories, where demonstrations were set up. A few years ago we took lecture demonstrations into the high school classrooms. Last summer faculty members suggested that we ask the high school classes to come to our laboratory and do an experiment themselves. We have designed each experiment so that the students have something to take back to their school with them, and in each experiment we have tried to incorporate an instrumental method.

Members of our faculty have written the experiments, which are sent to the high school students before their visit. One of our faculty members is present in the laboratory while the high school students are there. One or two second year students, who are familiar with the experiments also help the high school students. Of course, the high school teacher helps instruct the laboratory. A typical day starts at 9:00 A.M. with a tour of the entire campus conducted by an admissions officer. Returning to the laboratory, we start the experiments and continue until noon. The college buys lunch for the guests. We then return to the lab to complete the experiments.

The experiments we use include one on Spectrophotometry. Absorbance vs. wavelength of food colored water are plotted from a Spectronic 20 Spectrophotometer. Yellow and blue solutions are mixed and the students discover the adativity of absorbance. Details are discussed in full in each write up and also by the teacher. "Smilie Birds" are used to illustrate Hook's Law; then this principle is illustrated by running Infrared spectra of decane and deutrodecane, and cyclohexane and cyclohexene. Students take home visible and IR spectra plots.

A second experiment includes the final steps in the preparation of sulfanilamide using standard taperware and suction filtration. Agar plates are prepared and the students spread them with E. coli bacteria and place a small disc soaked in their sulfanilamide on the center. The take the plate with them and watch for a zone of inhibition of E. coli growth near their drug.

Another group fractionally distill an unknown mixture, run a gas chromatograph of each fraction; they then type data into a computer terminal, and the computer calculates per cent composition of each fraction. The students take the gas chromatography plots and the computer print out back to their school.

In a final experiment the students use an automatic buret, stirrer, pH meter, and a strip recorder to standardize a sodium hydroxide solution and to determine the strength of vinegar. They also titrate a sample of phosphoric acid as an example of polyprotic acid. The graphs of the titrations are taken back to their schools with them.

Pictures are taken of the students while they work. These are sent to the schools and also used by the college public relations department.

Our program can help the high school teacher do his job better by serving as a motivator. It involves a field trip to a college campus with a chance for interaction with college instructors and students. This is especially good because the students meet new people with new approaches to problem solving. It usually helps the high school teacher's image for his students to see him instructing in this different and advance situation. It is quite possible that the teacher may use one or more of the experiments when he returns to his own classroom. In today's society gadgetry fascinates and may serve to motivate students. Usually colleges have instrumentation which high schools cannot afford; thus High School Laboratory Day shares the wealth of the college. The advantage to the college is that the high school students get on the campus and see the college in operation. This may serve to interest them in the school. Often chemistry is taught to juniors; thus it is exposure to college at an ideal time.

The results of High School Laboratory Day are difficult to measure. The informal feed back from teachers and parents of students who have participated has been enthusiastic. The students have enjoyed and learned from their day on our campus. This attitude is reflected in their action while they are in our laboratory. It is difficult to find why students choose a particular school; however, we find students enrolling in school who have participated in Lab Day always greet us and identify themselves as having been at a High School Laboratory day.

While we have used this in the Vincennes University Chemistry Department, I feel that it could be made to work in other disciplines. This program evolved at Vincennes and was administered as a new idea. If someone else tries it, they should use our program as a spring board, but make it their own program because it will be their enthusiasm and work that make it successful. It takes much work to write and set up the experiments, and effort to make the day successful. We have found it well worth our effort.

Arm Chair Chemistry - The Seminole Model for Two-Year College - High School Articulation

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Presented to the symposium on Innovations in Teaching Chemistry, Environmental Science, and Environmental Technology related to Chemistry, Thirty Sixth Two-Year College Chemistry Conference, the Loop College of the Chicago City Colleges, Chicago, Illinois, August 24, 1973.

The efforts described resulted from a COSIP program for two-year colleges at the University of Oklahoma and the apparent needs of entering freshman students in chemistry at Seminole Junior College. A study was made to identify the problem and the following conclusions were reached:

1. Some schools were too small and poorly funded to provide a good chemistry program.
2. A few schools had young, inexperienced teachers with little knowledge of alternative methods of instruction and some had older teachers who needed to update their knowledge and experience.
3. Some schools were suffering from limited faculty and

overcrowded classes resulting in a lecture oriented chemistry course.

During the COSIP program Dr. Hubert Alyea demonstrated his "TOPS" and "Armchair" experiments and held training sessions. In addition to the value to their own instruction, the Seminole participants recognized the potential for use in the disadvantaged secondary schools mentioned above.

Invitations were sent out to the secondary science teachers and the value of such an approach was quickly recognized. As a result, Seminole Junior College obtained NSF funding for a four-week session at Seminole Junior College including funds for equipment and materials (Teacher's TOPS Kit, Projector, 8 student kits per teacher, lab guides, reagents for 1 year with carrying case for each participant). Twenty local teachers in the five county district were selected from schools which could not afford a traditional program, yet needed to offer chemistry, and agreed to implement the program if selected. Others selected were from schools offering chemistry, but with limited facilities or the faculty members themselves needed updating.

Initial results indicate that five schools will offer chemistry for the first time and the remaining schools will have an enhanced chemistry program. Sessions will be held during the year to determine if problems exist in using the techniques. In addition, it is anticipated that there will be a close working relationship between the high schools and Seminole Junior College. The presentor then demonstrated a few of the TOPS experiments and answered questions regarding the purchase of the materials and manuals.

A New Approach to the Development and Administration of General Chemistry Examinations in a Community College

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Presented to the Section on Evaluation of Student Work in College Chemistry, the Thirty-Third Two Year College Chemistry Conference, Dallas, Texas, April 7, 1973.

I have always felt that teaching has to be improved one step at a time and that this is continuous because you can just concentrate on one improvement. I felt that I was forced into concentrating on testing. I am sure you have had the same thing happen to you. A student says after he has taken an examination "I knew that material, I just couldn't write it down" or "I'd do fine if I could retake it. I know I know that material." I got in the habit of just saying "Here is another exam, take it". I had been teaching that way almost 10 years because it didn't matter to me whether he did it a particular hour or not and also the students didn't seem to have time to finish a test that I gave them. I would prepare an hour examination that I thought was quite reasonable and they would run out of time and this seemed to be a problem they shouldn't have to contend with. The enrollment in organic, which I was teaching, had fallen so badly because students were dropping out of general chemistry. This is why I felt I was forced into it. I needed the students. I ended up one fall with 8 students in organic chemistry. I had been getting 30 in the fall and finishing 10 in the spring so I felt I needed to improve the examination procedures and provide for retesting.

They needed the opportunity to schedule the exam when they felt ready to take it. I felt like they ought to have an opportunity to review and retake the test if they wanted to spend the time to do this. At the same time they would still be responsible for new material that was covered. This put a terrible load on the student. I wasn't completely unprepared for the way they accepted it. What I did was to rewrite all my organic chemistry exams into what I considered was four equivalent exams. From what you have heard here it of course would be better to do this by computer, which would eliminate a lot of the work that went into making and grading exams, but once you get it organized it really isn't too hard to handle. I think that possibly a few things that I have to say about the way we organized it would help with the computer type testing too. In other words, you would have a plan to put into effect, perhaps a little more effectively. Maybe you would then do this type of thing if you didn't have time up to now.

I set them up in what is called our activity periods on Tuesday and Thursday afternoons. There are two hours many times in which no classes are scheduled. Every student came in and took the first test. They can retake the test until the next progress test is due. With a block of about five weeks on a 16 trimester, they would then be able to retake that test for about four weeks, but they had to come in and review the first test they had taken and study it so that optimistically they would show improvement on the next test. The thing that they like best is taking the examination. You learn a lot from a test as you all know. They have an opportunity to go over it immediately. They have review sections set up so that usually what we have would be answers prepared in detail saying this question is designed to test you on a particular principle and then give considerable explanation. They can come in and look at their test paper and they can project this and they use it together. Two or three people will come in and will discuss it together. They will retake the test and surprisingly they will make one or two points higher than they did on the first test. You would think that this would discourage them because here they have taken the test on their own time, spending time reviewing and studying, still trying to keep up with the new material, and they want to take not one test but four tests, because they say they learn so much from going over the questions. Therefore they do not mind having the test given outside of class time. This made a lot of interaction. I found a closer personal relationship. I was doing more individual tutoring than I had ever done before, simply because the students were much more interested. The main actual advantage has been as a teaching tool rather than for improving grades. The next surprise came when I had my standardized final exams and I found out that I was about 20 percentile points higher on standardized exams than I had even been before. Now I was not using those questions to test them with so it seems to me that this results in some improvement. What I have done here is to outline how the system is working now.

I give an outline to each of my sections of chemistry that I am testing. The first time was with 10 organic students in the second semester and they were very capable students. The next time I tried it I taught 65 students in first semester general chemistry, one section which had 30 students for second semester general chemistry, and the first semester of organic chemistry with 30 students. Of the 65 beginning general chemistry students made up of engineers and pre-meds about 60 finished the course and there was one "D". At the end of the second semester I finished 57 students and had one more "D". I had taught chemistry for 14 years and nothing like that had happened to me before. Usually 50% finished, sometimes as low as 30% finished. I couldn't say that it is just the testing that does it. It might be just the system itself - giving them a lot more time with the teacher. They take three progress tests for each semester representing the sections I am teaching.

When the material for each test has been covered the student has two options. He comes into the class and goes over the practice tests or he simply goes down to the testing station to take the progress test without bothering to review. When we first started a lot of them would do that, but now hardly any do because they know that they can do a better job at a regular testing time. They like the extra time. If he comes in during the class time he only has one hour whereas the testing schedule allows up to two hours if needed. They use about an hour and fifteen minutes, but they are not under pressure if extra time is needed. Not all get through in the same time.

We set up a few rules. He gets the highest grade no matter how many times he takes the exam. He has more time, he can postpone the test if he has a headache and can take it several times. He never takes the same test twice and has to wait a week between tests. They can only take tests at testing time to maintain a testing atmosphere. I do know that they have incorporated some of these ideas in the general chemistry at South Florida as I have a daughter going to school there, so I get feedback, and she said the cheating was so bad that it was just a farce. She said she actually know students who had gone in and had been able to give tests to someone else to fill out because the room was so crowded and then they handed it in as their own. If I have more people than will fill the seats in the room, I just say that they will have to wait until another time. This is a little hardship if they come in ready for a test at a certain time, but it happens so seldom. They check with me ahead of time. Nearly everyone that I teach wants me to know when they are ready to take the test. When it looks like there will be too many, I will suggest another time. The students realize that you can only want them to succeed and they do this willingly.

What is required? They must first have the set of objectives that clearly states what they are going to be expected to know because they will have different professors. Then they will need a time schedule that gives them places and times for exams. General and organic tests may be at the same time. There must be someone present for the exams which presents a problem. I have two assistants who know the students well. The students want to know their grade almost immediately but we do not give out the grades for a week because the exam will be used for a week. There is not usually too much trading of questions. If I feel that there has been, I simply use another test. They have to wait a week and then come in and go over their test with a lab assistant. They can also sit in on a review session. They have a review session before they take a retest as they felt they needed it. They asked for the review session.

I have thus eliminated testing from my classes which has given me a few more hours that would have been used for testing so now I only have to review the tests in class. After giving the tests the first three times, it is possible to schedule a lecture going over the tests. This is helpful because the majority are going to take all four tests. They are not all in at the same time as most of our students are working.

It sound like we are spending all the time testing but this is really not true. Most of the time is spent with the students discussing these tests and learning from each other. It is no doubt a recycling program. I was in a position to check myself as I had used the standardized test 12 years. There is no doubt that it improved their grades tremendously. For about four semesters they have stayed in the course.

Questions following the presentation:

Is there a tendency to procrastinate?
Answer: Only on the first test

What type questions are used?
Answer: 20-25 short answer, no true-false. These are taken from a file of test questions in accord with the objectives.

When are questions answered?
Answer: During usual advisement time

The ACS General Chemistry Examination: Some New Ideas

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Presented at the Thirty-Third Two-Year College Conference, Dallas, Texas, April 7, 1973.

I have had a strong feeling that we have had about the same general chemistry examination for a good number of years. It is not a bad examination. I have never said that and I think the chemical community owes the people who have been responsible for its development a deep debt of gratitude. These examinations have been very worthwhile. I have also felt over the past several years when I have been using one or more of the examinations to evaluate students in advanced standing that I was not able to use them in the way in which I like to use them; to say, yes, you are very well equipped in certain areas of chemistry. There are some areas where you are extremely deficient. There are other areas you are just so so. There are some areas that I think you are doing nothing but recalling from a high school chemistry course. In order to get to that I had to go through 60 questions or 120 questions and pick out, well this question is structure, this question is organic and even I am able to say when a question is more or less organic. There are other areas where they were distributed right through the course. This was a place where I thought we might have some changes.

The idea of evaluation I am also feeling a little bit schizophrenic about because I just gave a paper at Mt. Holyoke on the other side of the coin: the evaluation of us by the student and I have had a lot of fun looking at various kinds of evaluation techniques. I think you and I are primarily concerned and have a very deep concern about our success or failure in our presentation of material. There are so many different kinds of things we try to do. We try to say we are going to make a thinking person out of you and we really feel that sincerely, on our part. I remember one student who was on the borderline of dishonesty and copied the periodic table on his fingernails. He was very chagrined to find the periodic table in front of him at all times and he had all this wonderful information that he thought would be useful. That is the kind of thing that is recall and a thing we don't expect to burden the student's mind with bits and pieces of information. We use questions that we think will probe the student's mind.

Our general chemistry examination or any other examination, I think, should be directed in that way. How can we best get a maximum amount of information in a very short period of time, though 105 minutes is a longer period of time that you or I have for a class period but it is a fairly short period of time to try to evaluate our success or failure in a teaching operation. Each two to three years, and it should be every two years, a committee that has some hold over and some new blood on it usually goes through a very involved operation of accumulating questions, evaluating these questions, getting correlation factors, coefficients, finding out what questions tell us nothing - they are either too hard or too easy, and most of this is statistical type of information brought by Ted Ashford at the University of South Florida. I will review a little of the mechanics for getting together such an examination. The chairman of the committee should be appointed far enough ahead of time so that he can overlap with the previous committee and to then create a committee that will have some people on it that are able to act as resource persons from past examinations. Then you go through a period of about two years or so in which you accumulate new questions. New areas are investigated. This is a fair amount of secretarial work for the chairman to see that these new questions are circulated to the committee. You try to operate at a level of about 20-25 people on the committee. You will have other collaborators, but the committee itself is primarily responsible for the testing procedures. You would like to have about 600-800 students evaluate the examination itself. You don't want a large number of students from one university. I thought once that it would be easy as I have 1000 students with 250 students in my smallest class, so I wouldn't have to do very much work there, I could do it all right there at Minnesota. That is not a good evaluation technique. You want to have at least eight different institutions probably with no more than 50-75 papers from any one institution. Otherwise you would have a very distorted picture of what is being taught over the United States. Finally you create two examinations and have them tested by these various groups, and an A and a B form. This will be a total of about 120-140 questions. They come back then to the testing center at the University of South Florida and each question is evaluated and a norm is established and you go through the operation of taking the performance of the top 25% and the bottom 25% of the number taking the examination. Where do they stand? Has it been a question that doesn't test them at all because it is too easy or so hard nobody gets it right? Then you look at the center group and find out the discrimination factor there. When you have come up with enough questions that are either:

A. Crossed because they are good or
B. Double crossed because they meet all the criteria or
C. It is not discriminatory
D. Too difficult

Then you work down to about 60 questions for the final examination. This process takes about two years. We are, in my case, aiming for 1975. If you don't get an exam every two years you are probably going to be in financial difficulty because the schools look for this rotation about every two years. If you don't have it they will either lost interest in the examination of perhaps use some other, a CLEP form, or one of the other exams, or else create their own. They are not a trivial thing as far as costs are concerned. The initial expenditure is very heavy.

There are four different things that I would like to see done to this examination. I would like to see a breakdown in subject matter. I started out with some 20 areas of investigation that I thought would test the student's ability to work in a certain area. It started with the very fundamental conversion of units of measure and so on. Maybe we can throw this out completely. I recognize its importance, but maybe we are not getting the best information by asking him to compute the volume of a sphere. In stoichiometry itself I think that does serve as a very important and very basic niche of our instruction. It is not the most exciting thing to teach, but it is a very important thing to teach, and if they don't understand this, then basics of common structure will be lost.

Whether you are of the macro school and do crystal structure and thermodynamics first or whether you are of the structural school and take up the building blocks of nature first, there should be an understanding of atomic and molecular structure.

The area of the gaseous state raises a question. Is this physics or chemistry? Are we supposed to expect the entire picture from high school or are we to continue to teach the basics of kinetic molecular theory and the gaseous state? I feel we still have the obligation for the student to understand the gaseous state.

The solid state and liquid state can be grouped together in the states of matter. I would have 10-14 questions on the states of matter.

Then we could move into areas of thermodynamics, energetics, dynamics, organic, nuclear and such. You can make a long list or a short list, but I would like to see these grouped somehow. When I talk with Ted about this sort of thing he doesn't discourage me, he simply says that we have a very large audience; we would like to keep that audience. I agree I would like to see it instead of 20,000 or 30,000 about 50,000. Perhaps the teacher could then see an additional use for this examination. You don't have to have a full year course. You get something useful out of it. If we had norms for the subdivisions the teacher could use the norms for parts of the examination relating to the areas covered. This would make the test more adaptable to courses of different types and of different term lengths, such as quarter and semester courses. The test could be used on a pretest and post test basis to find what the student knew from high school about the various areas and the test could be given again at the end of the course.

I would like to see some new questions developed on topics as those relating to material science and to the environment.

I do not think laboratory evaluation is incorporated into the current exam. Ted Ashford said we all don't do laboratory alike. I agree with that. Some courses don't have any laboratory at all but can't this be an addendum to the examination so these laboratory questions would not be part of the overall norm of the exam? Students do a respectable job on our ACS examination, but this is a laboratory course, and we don't know if he can tell a test tube from a balance. I think some black line drawing questions could be devised. I think some pictorial approaches to laboratory work or the reading of certain kinds of instruments could be devised. Titration operations such as the manipulation of a buret, a pipet, the treatment of balances are examples of skills from the laboratory that I would like to see the student examined on so that laboratory skills of students could be compared relatively in the same way that the subject matter norms are being used.

I am not sure that the 60 little a, b, c, or 1, 2, 3, 4 checking operation or multiple choice question tests is the optimum way of evaluating performance. I would like to see something which I will call macro questions, questions in which there may be 10 or 15 different things they will be asked about. Paragraphs might have consistencies and inconsistencies and have them to be evaluated as "good", "bad", or "not enough information to evaluate". Ted keeps saying we have tried this before and it hasn't worked, maybe he is right, but we have to try them, I think. Macro questions, such as a series based on the periodic chart, or a phase diagram are reasoning questions while too often multiple choice does not test in depth. They take longer, but maybe 10 minutes could be added to the exam. These questions would test the ability to read and interpret properly.

In summary, I would like to see questions put in groups, more questions on material science and environmental chemistry, more laboratory questions, and macro questions on the general chemistry examination.

DISCUSSION

The question was raised as to whether questions should be arranged in order of increasing difficulty. The reply was that the questions are being evaluated in terms of "ease" but they have always been scrambled. The comment was that students seem to do better when questions increase in difficulty.

An inquiry was about what was planned with respect to the increased amount of qualitative and quantitative analysis topics in first year chemistry.

A question was raised about the problem for the student in deciding on what he is supposed to do on the macro questions.

Future Trends in the General Chemistry Course

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Presented at the General Session, the Thirty Sixth Two-Year College Chemistry Conference, the Loop College of the Chicago Colleges, Chicago, Illinois, August 25, 1973.

Some major trends in the General Chemistry course include: (1) the development of more innovative, revolutionary chemistry course (2) the introduction of still more principles into the first year course, and (3) more use of descriptive chemistry by way of examples. The motto seems to be: "Let's put more chemistry back into the General Chemistry course."

Some of the goals that need to be followed are:

1. To present an overview of chemistry from electrons to biochemistry. Too many people who get a B.S. degree in chemistry have seen only the trees and not the forest.
2. To proceed logically from the simple to the complex.
3. To flesh out the course with today's chemistry.

4. To develop some basic essential skills, e.g. stoichiometry, bonding, structure, etc.

5. To emphasize the experimental nature of chemistry.

6. To add historical and relevant information as supporting material.

7. To practice economy, making wise use of time and resources.

If one hopes to give students a broader outlook, he cannot afford the time to cover everything that might be included in a first year chemistry course.

The material of General Chemistry might be organized into three parts:

I. Particles of Chemistry (electrons, atoms, ions, molecules)

II. Canonical Ensemble (matter in bulk)

III. Real Systems of Chemistry

Parts I and II must be covered economically if there is to be any time left to discuss Part III.

Questions and comments following the report:

What is your overall philosophy regarding the content of the freshman level chemistry course?

I think the first year in chemistry should be an encounter with as large a spectrum of the field as possible.

It seems to me that the laboratory program in most schools is somewhat inefficient. The trend now seems to be toward more talking about chemistry and less hands on chemistry in the laboratory for the sake of efficiency. How do you feel we can get more efficient use of student time, particularly in the lab?

I try to have the laboratory be an experience in the realities of science. It isn't always possible to coordinate the lab experience with the lecture material at that precise point in the course, but there should be some general correlation so that the laboratory adds support and reality to what is heard in the lecture. I have looked at the laboratory separates put out by Willard Grant, and I think this sort of thing provides enough variety so that individual lab exercises might be chosen so as to better mesh with and reinforce the lecture material.

I believe that students learn a lot of chemistry from the qual scheme. Students like qualitative analysis, but since these wet methods are not the way such analysis are actually done today, we wonder about the practicality of spending time teaching qualitative analysis. What is your opinion as to the value of the qual analysis scheme in the freshman course?

I'm all for it, but I think it should be limited to the laboratory portion of the course.

Would you describe the course in which you include qualitative analysis?

It is a five hour course with three lecture hours and two three hour laboratory sessions per week.

Could you give us an idea as to how you get descriptive chemistry into your General Chemistry course?

Well, for example, after building up a picture of the solid state, I talk about some solid materials. This is where I bring in the silicates and the metals. The first chapter in the book that is fully descriptive is the one on chemical periodicity. A student should be able to look at the periodic table and make some predicitions about the gross properties of the elements. We even discuss some extractive metallurgy in connection with the metals. After we have looked at the elements, then we take up their compounds, showing how properties change then we take up their compounds, showing how properties change across the table first for the oxides and then for the hydrides. Next we cover water in some detail and then go on to ternary compounds containing various elements in combination with both oxygen and hydrogen. Here we discuss the inorganic oxy acids as well as the organic alcohols, aldehydes, and acids. Certain reactions, such as substitution, can be introduced at this point. Similarities between organic and inorganic substances can be pointed out as well as their differences. For instance, borazine is a sort of inorganic benzene, and boron nitride is a non-carbon kind of diamond. The alkaline earth metals are contrasted with the Group IIB metals, and some mention of hard and soft acids and bases can be made at this time. It is when we take up the discussion of the transition metals that we go into the subject of stereochemistry. Transition metal compounds are classified as catalytic (e.g., permanganates). We also try to include as much organic chemistry as time permits, starting with the basics of structure and nomenclature.

I am interested in the chemistry course for engineers. At many schools only one semester of chemistry is now required for engineering students. I find that engineering students tend to think of chemistry as very unimportant.

Perhaps you will be interested in what we do at O.S.U. Chemistry is taught for two quarters to the engineering students and about one fourth of it is organic chemistry. Engineers should know something about organic molecules as well as inorganic molecules.

Do you notice any change in attitude of students when you get into descriptive chemistry? I find that students seem to lose interest in the course when I begin cataloguing the properties of the various chemical families.

I have had somewhat the same experience. The traditional presentation of the groups in the periodic table one by one can be very dull. The descriptive chemistry should remain in the course, but weaving the descriptive material into the discussion of principles makes more sense to me, and I think it is more interesting and meaningful to students when treated this way.

What do you include in the first year that is quantitative?

Such things as acid-base and redox titration, of course. We also do some gravimetric analysis. We even have the students do a Job plot in the exercise on complex formation. We introduce the freshmen to such instruments as pH meters, Spec 20 spectrophotometers, and gas chromatographs.

With our limited amount of equipment we have found it best to set up open labs. The student must get scheduled in to use the electroanalyzer or the Spec 20.

I think it would be great to add the IR spectrometer as well. I found that when we introduced some qualitative organic into our freshman honors course, the use of the IR for identification of functional groups was very exciting for the students. However, I try to keep the focus on the spectrometer.

What should we do about the use of SI units? Must we replace atm or torr with newtons per sq. meter?

I'll add to your question. What are we going to do about electrochemical potentials? The signs we are using now make more sense to me, and I would be reluctant to change. I guess if the A.C.S. did something in this area it would have to come out of a committee report and would be published in the Journal of Physical Chemistry.

We have wondered how far we should go with SI units in preparing the general A.C.S. exams.

Dr. Busch replied with a question: Well, what's the answer? The response was: Our answer was--not very far.

The closing comment was I think much of this will be decided by the textbook writers. As SI units are used more completely in new textbooks, instructors will follow suit.

Future Trends in Chemistry for the Underprepared

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Presented to the General Session, the Thirty Sixth Two-Year College Chemistry Conference, the Loop College of the Chicago City Colleges, Chicago, Illinois, August 25, 1973.

Future trends suggest three main areas of development:

(a) an increase in individualization of instruction (b) a more careful selection of topics for emphasis and (c) a movement toward humanization.

Individualization

The freshman science majors course has been individualized to a great extent. Combination lecture-demonstration-discussion sessions are scheduled three times weekly as is a three hour lab which is correlated to the lecture topics. The lecture sets a pace, but the student is not bound to that pace. Explicit behavioral objectives are provided and the student decides, when he feels he has mastered the material, to go to the Learning Center and take the test. The test is given without limitations of time or supplementary materials. The instructor and student go over the exam together and if mastery is not demonstrated (90% correct) the student recycles. Grades are related to the number of units covered; A, B, C, or an I which is converted to another grade by the end of an additional semester, giving A, B, C, or F. The texts used are Cherim for the first part of the course and then the student's choice of Masterson and Slowinski, Mortimer, or Brescia, et. al. Lectures, even in an individualized approach, are necessary to stimulate, excite, and inspire the student.

Topic Solution:

Chemistry for the underprepared requires emphasis on fundamental skills of problem solving and understanding of basic concepts. For such students the following topics seem most relevant to needs:

1. Measurement
2. Basic Algebra
3. International and Metric units.
4. Formulas and Nomenclature
5. Writing and balancing equations; stoichiometric, equilibrium, redox, ionic, and nuclear
6. Factor label method
7. Gas laws
8. Solutions; concentration, effects, stoichiometry
9. Acid-base chemistry: Arrhenius to Lewis
10. Redox: reactions and titrations

Humanization:

By examining the nature, origin, and methods of science the conclusion is reached that science is involved in questions of values, standards of right and wrong, and social aims. We need to do more than give lip service to our concern for human dignity by demonstrating that we care about their problems and that we respect them as human beings.

General Chemistry

Robert Plane
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Presented to the General Session of Effective Teaching Through Relevance symposium, the Thirty-Seventh, Two-Year College Chemistry Conference, Monroe Community College, Rochester, New York, Oct. 13, 1973.

Today when life is more complicated, when there is so much to learn, when we can't learn it all, and the question of why these particular choices, and not others, the teach must justify at each stage what they want to get across and why. The student is not willing to accept it at face value.

We must keep in mind, as we teach, the following relationships:

1. Chemistry to other subjects. Students are not studying chemistry because of "their love for it" or for its intrinsic value, they are studying chemistry for its relationship to other sciences. Chemistry is a "useful science", it feeds all the other sciences whether it be biology, physics, engineering, agriculture or any other major science. Examples should be realistic and ones they may experience or observe, i.e. rusting or corrosion of iron.

2. Balance between observations and theory. The chemistry teacher owes it to the subject to correctly represent the science. The science is constantly fluctuating from heavy theory to heavy on the descriptive or observations. Frequently the proper balance between the observation and the theory is ignored. Todays general chemistry course is heavily oriented towards the theory, "turning-off" many students. The proper relationship between them must be stressed at each stage keeping in mind that the descriptive is more important than the theory.

   Chemistry is probably the hardest science course to teach because students do not or have not consciously experienced chemical reaction in everyday life. They have played with toys that work on physical principles and probably as children experiences raising pets or plants. These experiences serve as illustrations in course work, such as physics or biology which are lackinc in chemistry. In chemistry, the setting of the problem must first be accomplished, which is difficult when it has not existed in the student's mind before.

   Relevance involves showing the relationship between the body of theory and the body of observation.

3. Science and mankind. Chemistry for the advancement of mankind. Topics of nutrition, feeding the world for the betterment of mankind, environmental chemistry, the effects of chemicals on soil, water and air. Selection of such topics to illustrate chemical principles causes the student to realize that chemistry is not divorced from the everyday world and its problems.

   The scientist must begin to exercise value judgments. Science has avoided such responsibility, as determining where the harmful effects are outweighed by the beneficial effects. The sociologist, psychologist, and others as yet have also avoided this judgment responsibility, one of human value. "What's the use of it all?", maybe it should all be done away with.

If all of this can be worked into a general chemistry course, then maybe relevance has been achieved.

Second Year Chemistry

The Chemistry-Biology Interface in Organic Chemistry

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Presented at the General Session of the Thirty-Third Two-Year College Chemistry Conference, Dallas, Texas, April 7, 1973.

Today's biology major certainly needs a good chemistry background, but the chemical concepts required by the biology major may be different from or not as intensive as those required by chemistry majors. I have listed biology courses that have chemistry prerequisites and then shown those chemical concepts required by biology majors or these biology courses. As a result many schools are now offering separate courses for biology majors and health majors and in many cases this has necessitated the change from a one year organic course to a one semester organic course. Book publishers generally noted this trend and we are aware that in the last few years one semester texts have come on the market. These texts fall in two categories:

(1) Texts based on the chemical reactivity approach involving polarities of molecules, solubilities, acid-base theory, oxidation and reduction.

(2) Texts based on the more traditional functional group approach of reactions.

Both types of texts include at least 25% biochemical topics. I don't want to get into any controversy here as to which approach is better. It depends a great deal on who is teaching the course.

The important point is that all these texts will try to get in some biochemistry and they usually put that biochemistry at the very end. They squeeze it in so that if we get to it, it is okay, but if we don't, then they will take care of it in the biology courses. I think it can be done differently. I think the way to do it is to bring biochemical concepts in when you are teaching the organic chemistry. About two-thirds of the teaching is not relevant. I think what you want to do is show them how the knowledge of organic chemistry has direct bearing on the study of biological systems. What I have done is to choose the representative organic reactions and show the applications of these reactions to biochemistry. The major concern of biochemistry is to direct the student's attention to the reactions of the functional groups and not let him get confused by the greater complexity of the biochemical molecules.

One of the chief reactions of synthetic chemistry that occurs in biochemistry is esterification: Fatty acids and glycerol from fats and oils, phosphoric acid derivatives and sugars from phosphate esters such as ATP and fatty acids. In the esterification reaction you can show the student that it doesn't make any difference as far as the product is concerned whether the OH comes from the acid, the H from the alcohol or the H from the acid and the OH from the alcohol. What we then do is show how to use isotopic labeling with O^{18} in the alcohol and mass spectroscopy led to the correct elucidation of the esterification reaction.

Once the student understand simple esterification of acids and alcohols then it is easy to take up more complicated molecules. A very interesting molecule is salicyclic acid because it has both the acid group and the ester group in the same molecule. Two reactions can occur with salicyclic acid and what the other reactant is will determine what the product is:

Salicylic acid + acetic acid → aspirin
Salicylic acid + methanol → oil of wintergreen

Then we go to molecules of biochemical significance and we talk about glycerol and fatty acids. He knows the formula of glycerol from organic chemistry and all we are doing now is talking about an alcohol that has three hydroxy groups so therefore we need three acids to combine with it, but if he understands simple esterification, then it is not difficult for him to understand a fairly complicated esterification. We next talk about phosphate esters. Phosphate esters use phosphoric acid instead of fatty acids, and then we have compound lipids from phosphate esters. Finally once they see simple phosphate ester formation then they can understand phosphate ester formation between nucleotide molecules to form the long chains of nucleotides that we have in DNA and also to use phosphate ester linkages to convert ATP into ADP.

Another important synthetic reaction is the formation of the peptide bond which joins amino acids together to from proteins. The simple organic chemistry analog of this reaction is the synthesis of amides from carboxylic acids and ammonia. Once they understand the simple reaction it is easy to then bring in the formation of the peptide bonds, peptides, tripeptides and finally proteins. We first talk about simple amides, the reaction of ammonia and acids, we identify them with the amide linkages and say when we talk about reaction of two amino acids the peptide linkage is just an amide linkage but we are just simply talking about larger molecules. Taking two amino acids together a dipeptide is formed. The next step is with three amino acids together to form a tripeptide. Then differing combinations of the amino acids can be used to show what is important in all cases of peptides and proteins that there will always be a free amino group on one end and a free carboxyl group on the other end and all other amino groups and carboxyl groups will combine to form the peptide linkage.

The reversal of these synthetic reactions is hydrolysis. Hydrolysis is the most important biochemical reaction. When this reaction is carried on in organic chemistry it is usually catalyzed by acids and bases. In the body as in the case of most biochemical reactions it is usually catalyzed by enzymes. Hydrolysis of proteins yields amino acids. Hydrolysis of fats gives fatty acids and glycerol. Saponification of lipids yields glycerol and salts of fatty acids which are our soaps. In organic chemistry we are always talking about the reverse of esterification, the hydrolysis reaction. We talk about equilibrium. We bring in Le Chatelier's Principle. It is always a review of previous material. When you talk about simple hydrolysis then you talk about digestion of lipids. The hydrolysis of a simple lipid is identical to the hydrolysis of a simple ester.

Another extremely important group of organic reactions are the oxidation-reduction reactions of alcohols and carbonyl compounds. We talk about oxidation of secondary alcohols to ketones. An important concept for the students is to understand that although the oxidation-reduction reaction can be manifested in the gain of oxygen or loss of hydrogen,it is important that electrons are transferred. Here you have to go back and bring in half reactions students have heard the term "half reaction" in general chemistry but somehow in organic chemistry they get the feeling that they don't have to know that because that involves the sodium atom, that is, $Na \rightarrow Na^+ + e^-$ or $Fe^{++} \rightarrow Fe^{+++} + e^-$. Somehow we never seem to deal with oxidation-reduction as an electron transfer process in organic chemistry and I think we should. It is nothing of greater complexity. We do some rather complex half reaction balancing in general chemistry and I think you can do this in organic chemistry. It is essential to understand that electrons are transferred in the case of oxidation-reduction. The reason for that is that when he gets to metabolism the understanding of half reactions is essential in understanding the functioning of the Krebs Cycle and proton exchange. For example, one of the oxidation-reduction reactions in the Krebs Cycle is the oxidation of malic acid into oxaloacetic acid. Here the oxidizing agent is the coenzyme DPN. Some folks use NAD for the coenzyme. The point is that it is nothing more than the oxidation of a secondary alcohol to a ketone. Two hydrogens and two electrons are given up. These two electrons are picked up by the DPN also one of the hydrogens, the other hydrogen is picked up by blood buffers. The coenzyme is regenerated through the electron transport chain. That is the DPNH will pass those two electrons to the next coenzyme in the chain which is FAD and it will be regenerated back to DPN. The DPN will then be used to catalyze another malic acid oxaloacetic acid conversion. Electron transfer is where the energy comes from to synthesize ATP. Everybody talks about catalysis and says okay, I can flex a muscle, that has to do with ATP, but where the ATP is made and where the energy comes from is this sort of oxidation-reduction reaction which is really an organic reaction.

Next we have some simple organic reactions. Lots of times we talk about dehydration of alcohols to form alkenes. We talk about addition of unsymmetrical reagents to alkenes. The application of these reactions in biochemistry occurs again and again. In the Krebs Cycle we have dehydration followed by hydration in going from citric acid to isocitric acid. A molecule of water is lost, dehydration of an alcohol to form an alkene, then enzymatically that water is put back. It is put back in this case opposite to the way it came off. The OH came off the middle carbon. When isocitric acid was formed the OH was back on the second carbon. Here we can talk about specificity of enzymes and how substrate rests upon the enzyme and the reason for this type of thing happening in biochemistry because it would not happen in organic chemistry with an ordinary catalyst. The last three steps in a Krebs Cycle involve the dehydrogenation in going from an alkane to an alkene. The sequence is succinic, fumaric, malic, oxaloacetic. Those last three steps of the Krebs Cycle are identical with the first three steps of the fatty acid metabolism . In β oxidation of fatty acids the first steps are: alkane → alkene, in this case the coenzyme is FAD rather than succinic acid dehydrase. The FAD seems to be the coenzyme that removes hydrogen from saturated bodies while DPN and NAD is the coenzyme that will oxidize an alcohol to an aldehyde or an alcohol to a ketone. But again carbon-carbon single bonds - loss of hydrogens; carbon-carbon double bond adding water again a special reagent; in this case the enzyme directs the hydroxyl to the β carbon and then finally the oxidation of the secondary alcohol by the coenzyme DPN to form the ketone.

Decarboxylation reactions are talked about in organic chemistry with dicarboxylic acids. Depending on what the dicarboxylic acids are a variety of products can be formed. At 140^0 malonic acid loses CO_2. There are a lot of decarboxylation reactions in the Krebs Cycle, for example, oxalosuccinic acid is decarboxylated to α-keto-glutaric acid. Everybody knows CO_2 is a waste product of metabolism. It comes from the organic molecules that are being used as food in the body. It also comes from the decarboxylation of amino acids to form primary amines. The odor of decaying flesh comes from lysine and cadaverine. Ornithine and lysine are decarboxylated to form cadaverine and putricine, the two diamino compounds that cause the odor of decaying flesh.

Histidine is decarboxylated to give the compound called histamine. Students have heard of histamines and antihistamines. Histamines are compounds that cause increase of flow of gastric juices and cause dilation of the capillaries and the small blood vessels. Antihistamines are drugs that reduce the effect of allergic reactions by opposing the histamines.

In discussing keto-enol tautomerism somehow we always seem to use acetoacetic ester as the example. In carbohydrate metabolism there are two important keto-enol reactions. The interconversion of glucose and fructose through an intermediate explains why fructose gives a positive Benedict's test. It surprises some students that fructose, a ketonic sugar, will give the test. Dihydroxy acetone phosphate is convertible to glyceraldehyde-3-phosphate again by way of keto-enol tautomerism.

For the stereochemistry chapter of organic chemistry almost every biochemical compound is in one of two optically active forms and the body can only use one form. All natural sugars are D. All natural occuring amino acids are L. The L form of adrenaline is active. The L form of mono sodium glutamate is the food enhancer.

Geometric isomers are involved with pesticides. Lidane is one of six possible geometric isomers of hexachloro cyclohexane. Only the "dish" form has pesticide activity.

Acid-base chemistry goes back to general chemistry. We can talk about dissociation and distinguish between strong and weak acids. Once they understand the property of an acid as a proton donor and an amine as a proton acceptor, then that can be related to the amphoteric properties of an amino acid. The amino acids have the carboxyl group and the amino group in the same molecule and they can understand that the structure will depend on the pH.

Chemical Instrumentation

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Presented at the General Session of the Thirty-Fourth Two-Year College Chemistry Conference, Cuyahoga Community College, Cleveland, Ohio, May 11-12, 1973.

Several years ago at a regional chemistry conference, a debate took place among several chemistry teachers from 4 year institutions as to whether instrumentation was necessary at the lower division level. Some said that students would be greatly handicapped without knowledge of instruments and others said they didn't want students who had been using instruments because they want to train them themselves.

There is still some controversy about the necessity of instrumentation for college freshmen and even sophomores, beyond the pH meter, colorimeters, single-pan speed balances, and automatic titrimeter. How much beyond these should one do in freshman chemistry and in organic chemistry? How much can an institution support the acquisition costs of instruments and then, the maintenance costs? What kinds of modifications and or deletions must one make in the chemistry courses to incorporate more instrumentation, and even more importantly, how much is one willing to modify his course? How much time does a faculty member have to develop new approaches to his or her courses?

Many of these questions can only be answered on an institutional basis depending on the local situation. Some of the questions might be answered on a regional or national level and the committee on chemistry in the two-year colleges has gathered some information to attempt to answer the question of how much and what kind of instruments are being used and or can be used in college freshman and sophomore chemistry.

What I plan to do is summarize the findings of the committee on chemistry in the two-year colleges based on a national questionnaire sent out one year ago this month. This information may be useful to some of you in asking your administration for more financial assistance in the purchase of chemical instruments. In some instances it may assist in terms of your making a decision to use more instrumentation in lower division chemistry.

On May 16, 1972, 598 questionnaires were mailed out to 2-year colleges throughout the United States with special attention to geographic distribution. By June 16, 280 questionnaires had been returned, a response of 46.8%. The types of institutions polled and the percentages of responses were as follows:

Types of Institutions and Percentage of Response

Two-year Community Colleges	215	(7618%)
Two-year Private Colleges	28	(10.0%)
Two-year Technical Institutes	25	(8.9%)
Two-year Branch Colleges	12	(4.3%)

Two types of data were tabulated. The first was the student/instrument ratio, herein called the s/i. The calculations of s/i resulted in ranges of 0-2 (as optimum), 2-5, 5-10, 10-15, 15-20 and greater than 20. The second type of tabulation was the course in which the instrument was used at a particular type of institution. Specific data on instruments follows (based on two-year community and two-year private colleges):

PHOTOMETRIC INSTRUMENTS

Colorimetric

	Student/Instrument						
	% Available	0-2	2-5	5-10	10-15	15-20	20
Two-Year C.C.	61.9	4.6	31.5	26.9	20.8	8.5	7.8
Two-Year P.C.	52.0	0.0	30.8	30.8	15.4	7.6	15.4

This was used primarily in General Chemistry.

The fluorometric and nephelometric instruments were available to institutions in the 7-12% range. Detailed information about these are available in the tabulations of the questionnaire.

SPECTROPHOTOMETRIC INSTRUMENTS

Visible

	Student/Instrument						
	% Available	0-2	2-5	5-10	10-15	15-20	20
Two-Year C.C.	57.9	8.3	21.5	33.0	20.7	9.1	7.4
Two-Year P.C.	50.0	7.1	21.4	35.0	0.0	21.4	14.3

Two-Year C.C.	Used in General Chemistry	63.5%
	Used in Analytical Chemistry	60.0%
Two-Year P.C.	Used in General Chemistry	92.8%
	Used in Analytical Chemistry	42.8%

SPECTROPHOTOMETRIC INSTRUMENTS

Infra-Red

	Student/Instrument						
	% Available	0-2	2-5	5-10	10-15	15-20	20
Two-Year C.C.	63.8	0.0	6.1	23.5	37.1	15.9	17.4
Two-Year P.C.	28.6	12.5	25.0	25.0	37.5	0.0	0.0

This was used primarily in Organic Chemistry.

Other spectrophotometric instruments used include the Ultraviolet (28.8% C.C., 714% P.C.), the Flame (14.8% C.C., 10.7% P.C.), the Atomic Absorption (14.8% C.C., 3.7% P.C.), NMR (6.1% C.C., 0% P.C.), and the Mass Spec (1.9% C.C., 0% P.C.).

ELECTROMETRIC INSTRUMENTS

pH Meters

		Student/Instrument					
	% Available	0-2	2-5	5-10	10-15	15-20	20
Two-Year C.C.	98.5	14.6	3814	30.8	8.6	3.5	4.0
Two-Year P.C.	85.2	8.7	43.5	26.1	4.3	13.0	4.3

This was used in all courses, primarily in General Chemistry.

Other electrometric instruments have been categorized as follows:

ELECTROMETRIC INSTRUMENTS

	% available in C.C.	% available in P.C.
Titrators (all kinds)	21.6	11.1
Conductometric	10.4	0.0
Polarography	17.0	7.1
Electrodeposition	25.1	14.3

The two-pan balances are still being used, more by the private colleges than by any other type institution and primarily in the Freshman courses. Almost all institutions have single pan balances (88% C.C., 85.2% P.C.) and top-loader balances are available (65.8% C.C., 44.4% P.C.).

The next chart summarizes several types of instruments without regard to the s/i ratio, although the specific information is available in the questionnaire.

	% AVAILABILITY	
INSTRUMENT	Two-Year C.C.	Two-Year P.C.
Electrobalance	30.5	35.7
Recorders	46.0	29.6
Melting Point Apparatus	61.3	51.8
Gas Chromatographs	62.2	21.4
Refractometers	40.9	21.4
Polarimeters	34.5	17.8
Electrophoresis	15.1	14.3
Counters, Radiation	37.9	48.1

As one can see from the data, the Two-Year Private Colleges do not have the same access to equipment as the Two-Year Community Colleges. The Two-Year Technical Institutes also generally have a higher percentage of availability of instruments than do the private schools. There probably are many reasons for which I will not attempt to get into. There is one question which each of us should ask. "Do we need these instruments for students to succeed, whether they transfer to 4-year institutions or go into the industrial world?"

The next phase in our search for information is to determine what is being used in lower division chemistry at 4-year institutions. Perhaps we can then say whether or not students will be handicapped if instruments are not available in the 2-year colleges.

More important than the handicap question however, is that is we have instruments, make them available for student use. I base this on the statement of one of my students after a semester of organic chemistry in which the analytical laboratory was fully available to him and others:

> "This investigation is by far the most interesting, valuable and rewarding project I have ever undertaken at Keystone. For a change I had a chance to do something on my own that had innumerable practical applications. Students want to be on their own and this type of laboratory provides the opportunity of originality. I hope for the benefit of future students, that this new attempt at an instrumental laboratory is continued and expanded to the fullest extent possible."[1]

The work done on the questionnaire has been supported by the Committee on Chemistry in the Two-Year College, Mr. William T. Mooney, Jr., Chairman and Major Advisor. Dr. Anthony Trujillo of San Juoquin Community College has coordinated the questionnaire mailing and tabulation.

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[1] C.G. Vlassis and Thomas G. Cupillari, "Instrumentation in Organic Chemistry, "J. Chem. Ed. Vol. 47, p. 400, May, 1970.

Future Trends in the Organic Chemistry Short Course

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Presented at the General Session, the Thirty Sixth Two-Year College Chemistry Conference, the Loop College of the Chicago Colleges, Chicago, Illinois August 25, 1973.

I see the short organic course as a variety of things for a variety of places. There is a basis for two different types of short organic course.

The first type is a one term terminal organic course designed for students interested in penetrating as deeply as possible in one term into biochemistry. In this category are certain majors in biology, geology, psychobiology and environmental science as well as students who take this course to meet science requirements. The course should be a broad sweep over principles of organic chemistry including systematic nomenclature, physical properties of organic molecules, stereochemistry, basic reaction types and a limited number of reaction mechanisms. Depending upon the interests of the instructor, additional reactions and mechanisms may be included. The structures and functions of mono-, di-, and polysaccharides, of amino acids, proteins and enzymes; of lipids and nucleic acids should be presented. The metabolism of one of these classes may be discussed. Time should be taken to lead students to topics of immediate concern--topics involving biochemistry and bioorganic chemistry, perhaps even at the cost of some traditional topics. One may discuss the biochemical basis for neuropharmacology or the chemistry of insect juvenile hormones or the mode of action of antibiotics. These topics have exciting chemistry which is accessible to the student. It is important to build the attitude that the student can indeed use organic chemistry, that it is accessible to the student, and that he can use it to acquire a deeper understanding of the world around him.

The second type of short organic course is a two term (one year) terminal course. These students will take no chemistry beyond the two terms. The most meaningful method of meeting this need is a one-term course in fundamentals of organic chemistry followed by one term of bioorganic chemistry. Most students who take a full year of organic chemistry co so because it is required as a supporting course for their major field of interest. Often it is required for admission to graduate work in the health or biological sciences. If indeed the course has a large service component, it is the obligation of those teaching the course to inquire of those requiring the course about such questions as:

1. Why do you require your students to take one year of organic chemistry?
2. What is it you expect them to be able to do after completing the course? (Specification of performance in behavioral terms is the most fruitful mode of communication.)
3. Does the course as presently constituted and taught do for your students whatever it is you want it to do?

We who teach organic chemistry have the obligation to enter into discussion with related fields in an effort to be certain that the content of our course represents a balance between what we know to be the core of organic chemistry and what it is that allied departments expect of students who have had the course.

During the coming year studies will be made at Beloit College to determine the way in which both chemistry and other disciplines can be best served with a one year course of organic chemistry. It will be proposed that all students take a course called Principles of Organic Chemistry followed by at least one of three follow up courses which will include Bioorganic Chemistry, Synthetic Organic Chemistry, and Physical

Organic Chemistry. The Principles course must provide a foundation in organic nomenclature, physical properties of organic molecules, acidity and basicity of functional groups, basic reaction types and a choice of reaction mechanisms. The content of the Principles course may be determined by just what students need to be able to do for subsequent courses. This is the greatest question.

To further explore the question of course content in short organic courses, it is proposed that those concerned involve themselves more deeply with:

a. The Curriculum Committee of the Division of Chemical Education. This committee is working to develop a topical outline for a core chemistry curriculum specified in behavioral or performance objective terms. The reports of various subcommittees will be published in the Journal of Chemical Education.

b. The Examination Committee of the Division of Chemical Education. This committee is presently developing a new standardized examination for the short organic course. One could learn much by knowing the view of the subcommittee on the role, scope, and content of the course.

In summary, two different needs for the short organic course were described. At the present time, most consideration and explanation should be given to the structure and content of the two term terminal sequence.

Comments and questions following the report:

Would you elaborate more on the three follow up courses in the second term?

The Principles of Organic course in the first term will be followed by at least one of three second term courses: Bioorganic Chemistry, Synthetic Organic Chemistry or Physical Organic Chemistry. Students could go into any one of the three. The Synthetic course is not needed before the Physical Organic course. If uses of the Grignard reaction were left out in the Principles course, the topic could be incorporated in the Synthetic Course. The Principles must be taught systematically. I use the text *Introduction to Organic and Biochemistry* by William H. Brown, Willard Grant Press. The chemistry of carbohydrates, proteins, and nucleic acids are not taught in the Principles course. It is saved for the Bioorganic course.

How far should you go with nomenclature?

Should we promote systematic nomenclature?

You have to teach some of both.

Would a chemistry major need all three second term courses? What are the prerequisites for the Principles course?

If a person is in pharmacology, he could take Principles and Bioorganic. Beloit has another course for chemistry majors. The prerequisite for the Principles course is one term of general chemistry.

It would seem that if a small school can teach only one of the follow up units, it would be better to teach a traditional package.

Will the course you have described be accepted for transfer if it is nontraditional?

I believe the course I have described will be the future trend. We who teach organic chemistry have the obligation to communicate with those requiring a course (e.g. medical schools) to ask why they want the course.

I teach an individualized sort of Keller Plan approach and also have been considering two routes for organic students. Students should know a few reactions, but they should know them well.

What type of laboratory program do you use for the two-term organic course which you described?

In the first term there is a three hour laboratory teaching the techniques of organic chemistry. Not many synthetic methods are used. In the second term there is a straight synthetic laboratory involving multi-step synthesis. The synthesis are mainly manipulation of functional groups. At this point of development they are not medically oriented. The bio-organic students have no laboratory at present but will have one in another year.

What about logistics? Who teaches all the courses if they are offered?

The follow up courses are staggered. We are on the tri-semester system. One course is offered each trimester so all three courses are taught each year. The instructors do the teaching.

Where is instrumentation introduced?

Instrumentation is introduced in the Principles course, but is dealt with most heavily in the Synthetic course where it is a useful tool.

Individualized Teaching Methods

Mediated Laboratory Instruction

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Presented at the symposium on Innovations in Teaching Chemistry, the Thirty Seventh Two-Year College Chemistry Conference, Monroe Community College, Rochester, New York, October 12, 1973.

The purpose of this paper is to outline how I am attempting to solve some problems that face most of us.

These problems are twofold: some are physical and others concern learning itself. The physical problems are these:

1. Lack of Space in the Laboratory.
This necessitates many laboratory sections. For example, I have one 24 station laboratory which must service 120 General Chemistry students in addition to about 100 students in the other chemistry courses. This means that there must be 6 laboratory sections of General Chemistry.

2. Additional Staff are needed to teach the Laboratory Sections.
One instructor cannot teach all sections but when different people are involved in the course on a part-time basis, coordination and quality of laboratory instruction become problems.

The learning problems are as follows:

1. The interest of the student must be aroused by the laboratory instructions so he will want to do the experiment and find the results for himself.
2. The exercise must be as relevant as possible to the students' interests yet make the point intended.
3. The laboratory instructions must solve communication problems which occur because of the variety of ways in which students best acquire information, such as through visual images, the written page, audio images and physical operations.
4. The written material traditionally used does not seem to be an effective means of communication. One can write a most interesting introduction to an experiment which discusses the theory or principle involved in relevant terms, but this does not necessarily mean the material will be digested.

5. A sufficiently large number of students just do not read any material before they come to the laboratory to perform an exercise.

The experiment I will use as an example is the Determination of Phosphates in Detergents, adapted from the Journal of Chemical Education, Volume 49, No. 1, January, 1972.

This is how the system works. The printed exercise, including a discussion of the importance of phosphates and the problems involved with their use, is handed out a week in advance along with the performance objectives for the experiment. The students are required to view two slide-sound series which are on reserve in the library. These slide-sound series show the student interesting and pertinent pictures or graphs and illustrations of the material discussed. The first series discusses the importance of phosphates, some of the problems involved with their use, and how the experiment is an example of the testing methods used to monitor phosphates present in the environment. Detergents have an advantage over soap, which are amplified by the phosphate added. The phosphate helps soften hard water, stabilize dirt particles as a colloid, buffer acid stains, and helps emulsify grease stains. Phosphate is a necessary constituent of fertilizers to promote plant growth. However, when it is washed into our water systems it also promotes aquatic plant growth. This clogs our streams, lowers the amount of oxygen available to animal life, and makes the water more acidic as the plant material decays. In addition, phosphorus is not the most abundant element, and we are diluting it all over the world. This waste must stop and to stop it our water systems must be monitored.

The second slide-sound series gives specific instructions for the experiment and shows how to do each step. The student can work through the slide-sound series with the printed exercise, at his own pace, repeating any part necessary to get all the instructions figured out before coming to the laboratory.

When the students arrive at the laboratory to perform the exercise they view a video taped review of the procedures. This is a fast moving review to freshen their memories and takes only 10-15 minutes of the three hour period. They perform the experiment with the guidance of the instructor. This experiment requires a laboratory report, including a small research paper on the uses of phosphate in their area of interest and a statement of what is or could be done to combat pollution in conjunction with that use. Other exercises simpler than this are completed by giving a quiz on the material rather than by asking for a report.

I believe this method of presenting the instructions for the laboratory helps solve the problems.

Each laboratory section gets exactly the same well-polished instructions, regardless of the time of day or instructor. The student becomes more interested in doing the exercise if he has been shown the relevance of the material, how it is done, and that it works. The relevance of the material is revealed in the written instructions and the slide-sound series.

With some digging we can make chemistry interesting. Since everything involves chemistry, let us put chemistry back into the everyday experience. The students can go at their own pace with the slide-sound series. This is an alternative to the "reading" approach. Maybe Sally can not read too well, but she can learn chemistry while she learns to read. From experience the students are more confident when they come to the laboratory because they know what to do and how to do it. They have also seen some relevance for doing the experiment and seem to want to do the experiment.

The Keller Plan and it's Application to a Relevant Nonscience Majors Course

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This article deals with my initial experience in implementing the Keller Plan in conjunction with a newly devised, more relevant curriculum in a one semester nonscience majors chemistry course at Boro of Manhattan Community College (BMCC) of CUNY during the spring term of 1972.

Before devising the curriculum the eight members of the chemistry group within the BMCC science department gave careful thought to the type of student who would be taking the course. Since the inception of CUNY's open enrollment policy in fall 1970, the nature of the BMCC student had undergone a sudden metamorphosis. Cohen (1972) of BMCC's Office of Institutional Research compiled the salient characteristics of this new breed of open enrollment student entering BMCC in the spring of 1972. His major findings indicated the following properties of freshmen entering BMCC in the spring of 1972:

1. The average age of entrants approached 24 years.
2. Only 26% of the freshmen entering had graduated from high school within the past year.
3. More than half (50.5%) of all entrants had high school averages below 70%.
4. Nearly all entrants expressed the need for remedial attention.

5. 67% of the entrants came from families whose annual income was less than $7,000.

6. 94% of the entrants expressed the desire to someday obtain a bachelor's degree.

A survey of student interests taken by instructors teaching the one semester nonscience oriented chemistry course during the spring 1972 term showed that students were career oriented (mentioning careers in elementary education, law, advertising, sales and social work) and concerned with social issues.

Considering the mature nature, the concern for social issues and the poor mathematical backgrounds of BMCC students, we felt that a traditional one semester nonmajor chemistry course which merely surveyed classical chemistry and was a mini-course of the one year course for chemistry majors was inappropriate. Instead we decided an avant-garde course (such as the new nonmajor courses discussed at the Mt. Holyoke Conference on Education in Chemistry 1972 and at the 165th American Chemical Society's national meeting) which stressed chemistry for the citizen was more suitable. We felt such a chemistry for citizens course would be valuable for our students because it would be relevant to their lives. They expect to be engaged in nonscience careers but they show a concern for important social issues many of which involve the chemical enterprise such as air and water pollution, drug abuse and population control. They are concerned with health and diet and want to be intelligent consumers and are therefore concerned with food additives and their consequences. They are concerned with the future quality of life and are curious about DNA and its implications.

The best way to present a chemistry course for citizens, we felt, would be to succinctly and nonmathematically present the major concepts of chemistry and the relevant applications of chemistry to everyday life, then to show how these principles of chemistry effect these applications of chemistry. It would also be desirable to have students learn about and experience some of the work of both industrial and research chemists. To have students improve their objective thinking ability and become more independent learners who will continue to keep informed about scientific developments by reading the newspaper and popular magazines would be another important aim of a nonmajor chemistry course concerned with producing informed citizens. It would also be of value to develop or reinforce the attitude that the active, responsible citizen can participate in the shaping of the quality of life by being aware of and concerned with the developments of the scientific enterprise. In brief the major aims and objectives of the nonmajor chemistry course for BMCC students would be:

1. To produce citizens informed about and concerned with the role of the chemical enterprise.

2. To present succinctly, nonmathematically and concretely the major concepts of chemistry and the relevant applications of chemistry to everyday life: then to show the

interrelationship between these concepts and applications.

3. To appreciate and experience the type of work performed by both industrial and research chemists.
4. To improve objective thinking ability and develop independent learners concerned with continuing the learning process in science.
5. To develop or reinforce the attitude that the quality of life can be determined by active, responsible citizens who are concerned with and aware of the developments of the scientific enterprise.

We chose the textbook Chemistry for Changing Times by John W. Hill and published by Burgess Publishing Company, 1972, because we felt it quite compatible with our objectives. In presenting his information, Hill generally relates facts and concepts in a concrete, simple and nonmathematical form. In his early chapters (namely chapters 3-7) Hill presents the major chemical concepts that matter is built up from smaller, submicroscopic particles and that small variations in the structure and bonding of molecules causes differences in the properties of macroscopic objects. He presents these concepts in a historical context relating the thinking or experimentation of Democritus, Dalton, Thomson, Rutherford and Kekule and giving the rationale for the conclusions they reached. Starting with chapter 8 entitles "The Plastics", Hill deals with current, relevant topics such as foods, drugs and air and water pollution. He no longer presents the historical context, but instead simply states the pertinent facts and concepts and relates these to current social problems such as the problems of waste disposal of plastics, the legalization of marijuana and the dangers of food additives. Thus he focuses on the impact of science and technology upon society. Although he often takes a stand on these social issues, he presents these issues fairly and honestly never losing sight of the fact that these are multi-faceted issues. Hill has an optimistic tone, implying that science and technology offers mankind the mechanism to deal with these problems if man utilizes science and technology wisely.

It was decided to implement the Keller Plan under my supervision on a trial basis in 4 of 8 nonmajor chemistry sections because it was felt that it offered instructional advantages for open enrollment students. The Keller Plan also known as the Personalized System of Instruction (PSI) is a self-paced, student proctored, mastery oriented instructional method which is based on the psychology of this instructional strategy as described by Keller (1968) are:

1. The self-paced feature which permits a student to move through the course at a speed commensurate with his ability and other demands upon his time.
2. The unit-perfection requirement which lets the student go ahead to new material only after demonstrating mastery.

3. The use of lectures and demonstrations as vehicles of motivation rather than as sources of critical information.

4. The use of student proctors, which permits repeated testing, immediate scoring, readily available tutoring and a marked enhancement of the personal-social aspect of the educational process.

The Keller unit consisted of a textbook reading assignment, collateral references when appropriate, a list of instructional objectives and a homework assignment.

The one semester nonmajor chemistry course meets for five hours each week. Usually three hours are for lecture and two hours for lab. However, the first day of the term students in the Keller sections were informed that:

1. The work of the course had been divided into 14 units and for each unit they would receive a textbook reading assignment, instructional objectives and a homework assignment. Eventually we reduced the number of units to 12 and made the remaining two units extra credit because instructors found that they would only be able to cover 12 units in their conventional lecture sections.

2. These units would come in a definite numerical order and mastery of each unit would be demonstrated by passing a 10 question sentence completion exam with a grade of 100% before proceeding to the next unit. A student could take the unit exams whenever he felt ready and would be allowed to take equivalent forms of each unit exam as many times as necessary without penalty to his grade. In a given Keller section it was found that students averaged 1.4 tries to pass a unit exam and that 90% of the students finished all 12 units. 10% even finished the two extra credit units.

3. For two of the three scheduled lecture hours each week, the lecture room would be turned into a study hall where students could study individually or in small groups. Also they could consult with undergraduate tutors and the course instructor. The course instructor would also administer and immediately grade the unit exams. During the first lecture hour each week, the instructor would deliver a motivational lecture geared to the unit of an average pace. During the two laboratory hours, students would perform the regularly scheduled experiments.

4. Passing all the unit exams would guarantee a student a grade of B. In order to earn an A grade, a student would have to achieve an A grade on the regularly wcheduled midterm and noncumulative final exams which would be 50 multiple choice questions each. (The conventionally taught sections took the same midterm and noncumulative final exams).

We felt one advantage of the Keller Plan was that it offered a humane method of testing which would be especially appropriate to the more mature open enrollment student. We seemed to have been correct on this estimate since students readily commented that they enjoyed not having to take exams until they felt ready for them and they felt less pressured knowing they could retake an equivalent unit test without jeopardizing their guaranteed B grade. They also like the concept of the guaranteed B grade because they felt that it guaranteed success if they did their work.

Another advantage of the Keller Plan we felt was that by use of instructional objectives for each unit we would be able to spell out for the student all the important points of each unit. Thus the instructional objectives plus the homework assignments would serve as a quality control check to insure the student that he didn't miss any of the main points of the unit. By leading the student to the main points of each unit, we hoped eventually to improve his textbook reading skills. By showing the student that he could study a unit by himself and eventually pass a unit test, we hoped to show the student he could succeed as an independent learner. By continually subjecting the student to objective sentence completion unit tests and objective multiple choice midterm and noncumulative final exams we hoped to impress the student with the need for objective thinking and to develop his objective thinking ability. By requiring a passing grade of 100% on the unit tests, we hoped to develop in the student a sense of excellence. We can't be sure if the Keller Plan accomplished these desired results. But students did frequently comment that they liked having objectives because they liked always knowing what they were responsible for. Although initially students frequently complained that 80% would be a fairer passing grade on the unit exams since passing all unit exams only guaranteed a grade of B, eventually they stopped complaining. Hopefully this was indicative of developing a sense of excellence. That 90% of the students in a given Keller section succeeded in passing all the unit tests hopefully indicated to these students that they can succeed as independent or quasi-independent learners and perhaps they will continue the independent learning process in science by keeping abreast of science articles in newspapers and popular magazines. Further evidence of independent learning was demonstrated by students rarely consulting with tutors on more than two objectives per unit even though they did claim that they liked the presence of student tutors and found them helpful, considerate and easy to talk to.

The motivational lecture according to Keller was merely to stimulate the student to study the unit and to reward him for keeping up with the average pace set by the instructor. However, we found these lectures an excellent opportunity to introduce flexibility and flavor into the course thus offsetting some of the rigidity of the instructional objectives. We thus felt that we had the best of both worlds, a well defined course via instructional objectives, but yet no lack of flexibility or loss of flavor because of the motivational lecture. Course instructors met each week with me to discuss the content of the motivational lecture. On the unit dealing with food additives, the course instructors brought a package of Morton's Lemon Cream Pie to class. We then read the ingredients which included sorbitol 80, gum acacia, artificial flavor and sodium benzoate. However, no lemon and no cream was present in this lemon cream pie. The instructors then pointed out that sorbitol 80 in larger doses was present in a leading ant killer, that gum acacia was the major ingredient of chewing gum, which everyone from age five on knows isn't supposed to be swallowed, and that sodium benzoate in larger dosages was a deadly poison. A discussion then spontaneously broke out with both students and instructor giving their opinions on the moral, economic and medical aspects of the use of food additives as well as whether or not this present American generation was eating better than the previous generation. During the motivational lecture on commercial drugs, the pros and cons of allowing TV advertising of aspirin, considering that most of the claims made in these advertisements were false and that the continual suggestion that all life's tensions and problems could be cured by popping a pill leads to drug abuse, was discussed. The popularity of the motivational lectures was evidenced by the high attendance rate although attendance was never checked.

All four of us who used the Keller approach found it an interesting experience. Only one was not enthusiastic about trying the Keller method again. This instructor found the noise level in the room disturbing when he was tutoring students or grading unit exams, but he readily confessed that no student complained about the noise and that they seemed to go about their work enthusiastically. Perhaps a bigger classroom or a side room for the instructors would have alleviated this complaint. Furthermore he disliked grading papers with the student nearby although once again he readily agreed that students liked getting their grades immediately as well as their proximity to the instructor during the grading process. All the instructors disliked the clerical work the Keller Plan entailed such as filing unit exams in students' folders and charting the students' progress, but they generally agreed the effort was worth always knowing the pace of their students. Two instructors agreed with Lewis (1973) that the motivational lectures should be more substantiative.

Although with each mode of instruction considered the reading materials used in this course to be above average, 90% of the Keller students claimed to have read all or nearly all of the textbook material while only 50% of the conventionally instructed students claimed to have read all or nearly all of the textbook material. 90% of the Keller students claimed to have put above average effort into this course while only 45% of the conventionally instructed students claimed to have done so. The average scores of Keller students on tests was higher than the average test scores of conventionally instructed students on the common midterm and noncumulative final exams although no rigorous statistical comparison was attempted.

Since the feasibility of the Keller Plan in this more relevant nonmajor chemistry course has now been established, a careful comparison of four Keller instructed sections with four conventionally instructed sections with controlled conditions using ACS-NSTA Cooperative High School Chemistry Exam, Form 1971, scores as a pretest and the scores on the common midterm and noncumulative final exams as the posttest is currently in progress. A standardized course evaluation questionnaire developed by McFarland (1971) of the University of Texas will also be administered. I hope to report the results of this more rigorous comparison of the Keller Plan with conventional instruction in the near future.

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The Keller Plan for General Chemistry at the University of Michigan

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Presented to a Concurrent Special Topics Meeting, the Thirty Sixth, Two-Year College Chemistry Conference, the Loop College of the Chicago City Colleges, Chicago, Illinois, August 25, 1973.

The use of a modified Keller plan at the University of Michigan has been intended as exploration of its potential in large classes. It was first tried in smaller enrollment courses.

The lower enrollment course involved highly qualified well-motivated students, whose comparative test results did not indicate dramatic differences in comparison to conventionally taught courses, except they did not learn less. Student subjective response was very favorable.

The trial with a larger group of students, very heterogeneous in background and ability, resulted in test scores which were typical for that class in previous traditional sections, suggesting that no less was learned. No control group was used. There was a higher than normal completion rate. Student response was favorable. The lab remained scheduled during this trial.

Several modifications were introduced in the next trial. Lab was better correlated with units. The teaching fellow's role regarding tutor supervision was emphasized and tutor meetings concentrated more on discussion of course material. The student was required to do more work before taking or retaking exams, and occasional lectures on difficult topics were introduced. At least 90% are expected to complete the course with a C or better although they did not use the extra help as expected.

The Keller Plan is workable in large sections (more than 225) and was accepted favorable by the students provided sufficient tutors are available and mastery was set a B rather than A. Reservations include the economy and efficiency (although our tutors are paid in credits). It is clear that the faculty member can not reduce his participation before what is normally demanded in a lecture course.

The advantages appear to be in the attitudes of students and staff. The positive attitudes are difficult to ignore. There will probably be no expansion of the method to the large (1000-1500 students) sections but some courses will be continued to be taught by this method and may be made available to a reasonably sized section of the larger group on an optional basis.

Comments and Questions following the report:

Is there a distinction between tutors that you described and proctors as described by Keller?

No major distinction other than tutors do not keep grades at the University of Michigan.

Do you use aides such as cassette tapes, film loops, and other visual aides?

No aides other than tutors. This is something I would like to do.

What do you mean by students contract for a "B"?

If students complete all units they earn a "B", if they complete 90% they get a "C".

Do students need to spend more time in Keller courses, if so, do their grades suffer in other courses?

We have no actual figures on this and I do not know if this has been investigated.

I lose students in chemistry because the math department will not give incompletes with Keller courses. About 25% of my students finish, about 50% of my students who do not finish say that it is because of the time required by the Keller type math courses.

Do you use the complete set of the Dickerson, Gray and Height books? How does the self-paced format work when there are numerous errors in the text on problems?

We use only the main text. The tutors are alerted to the errors in the text on problems.

How does student competition compare for the Keller course and the regular course?

There is about a 10% drop rate in the second semester and as high as 25% in the first semester while in the Keller course there is only about a 5% drop rate.

How do students from Keller courses compare to those from regular courses when they take the next chemistry course, such as organic or quantitative analysis?

I have the general impression that Keller students do better than those coming from regular courses.

Do you think changes in students' attitudes come from the novelty of the Keller course?

Proabaly yes.

Do students become too dependent on objectives?

I don't know. After the student goes through a Keller type course maybe he will set up and organize his own objectives for non-Keller courses.

There is an important difference in circumstances between the programs at the two schools. At the University of Michigan the student gives up a Professor for an undergraduate tutor, while at the community college he has the opportunity to go one-to-one with the Professor.

Tutors learn the chemistry if no one else does.

The better students learn more thoroughly through tutoring other members of the class.

What do you do with the passive, withdrawn student who does not seek out help?

I try to seek them out, especially in the laboratory.

Auto-Tutorial Problem Solving Modules for General Chemistry

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Presented to the symposium on Innovations in Teaching Chemistry, Environmental Science, and Environmental Technology related to Chemistry, Thirty Sixth Two-Year College Chemistry Conference, the Loop College of the Chicago City Colleges, Chicago, Illinois, August 24, 1973.

The presentor, along with Robert E. Cathers, has developed a set of 36 auto-tutorial problem solving modules as one component of a multiphase package approach to the science majors course. Other phases include approximately 60 pages of notes which are passed out to students, laboratory with quantitative unknowns, and voluntary problem sessions, as well as lectures. The modules are not meant to stand alone.

Early modules for problem solving consists of an 8-12 page booklet and an audio cassette of 50-60 minutes in length. The printed material consists of a set of 5-30 problems (worked in detail) illustrating the major principles of the topic being treated and a concise review of the theory involved in the solutions. The audio tape is intended to guide the student through the worked problems, emphasizing the necessary theory, the method of attack, the reason for each step and the significance of the problem and result. The tape is keyed to the printed material by means of the tape counter reading, providing random access to the various parts.

The modules are available in the library and have been widely used.

Examples of the types of modules available are:

1. Math review
2. Lewis structure
3. Mole concept
4. Empirical formula and Percent composition
5. Calculations from equations: Stoichiometry
6. Calculations from equations: Limiting factor
7. Oxidation numbers and Formal charge
8. Nomenclature

In the opinion of the designers of this approach, lectures in reasonably small classes still serve as the most effective approach to teaching concepts and theories, in transmitting the excitement and stimulation of current research, and in motivation. The lecture is ineffective in developing laboratory skills and problem solving skills. In the latter cases the student must do it. It was this reasoning which led to the development of the modules in problem solving.

An Individualized Program in Organic Chemistry

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Presented to a Concurrent Special Topics Meeting the Thirty-Sixth Two-Year College Chemistry Conference, the Loop College of the Chicago City Colleges Chicago, Illinois, August 25, 1973.

The approach used is a modified Keller Plan. No junior or senior level students are available for assistance as tutors or exam graders. The students do a great deal of helping each other but basically consult with the instructor. The course is based on Organic Chemistry by Morrison and Boyd and is broken down into 14 units the first semester of the year course covering chapters

1 through 13 of the text, and 16 units the second semester covering chapters 14 through 32 and also chapter 37. Objectives and study guides have been written for each unit and have been revised each year. Supplementary material is also given with some units and some video taped aids have been made.

At the present time a grade of B is guaranteed for mastery of all units and experiments. Mastery is tested through written tests, which are graded immediately in the presence of the student, who is quizzed orally on his answers. A student may not begin the next unit until he has demonstrated mastery. Laboratory work is done on the same basis. If a student makes insufficient progress he or she may take an incomplete at the end of the first semester and finish during the second. This, most likely, precludes the completion of the full year of organic before the student would normally finish the two years at the community college. The major problem with this approach is procrastination on the part of the student and lack of ability of some to learn through the written word. To help alleviate the latter problem, video taped mini lectures have been prepared on the more difficult topics and are available from the library on video cassettes. Solving the procrastination problem is attempted through prodding and required attendance at discussion sessions.

With the small number of students taking organic chemistry, it is difficult to judge comparative methods of instruction. Subjective opinions plus the ACS Organic Test indicate that the students completing the year course have done better or as well as they would by traditional approaches. The method certainly catches and corrects deficiencies in the building of understanding before it is too late for the student. As in most courses the factual material may soon be forgotten, but hopefully the way an organic chemist thinks, how he analyzes, organizes and applies factual information will help the student to know where to start looking for answers should the need arise.

Chemistry at Paris Junior College

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Presented to the Agricultural Programs Section at the Thirty-Sixth Two-Year College Chemistry Conference, Chicago, Illinois, August 25, 1973.

Paris Junior College is located in Paris, Texas, about 100 miles northeast of the Dallas-Ft. Worth area. It has an enrollment of approximately 1300 students in full and part time studies.

Paris Junior College provides a wide variety of educational opportunities. Academic and preprofessional courses are offered for those students who plan to transfer to a senior college in order to complete a baccalaureate degree program. Applied Science Instruction (vocational-technical) is offered in several fields for those students who do not plan to continue their education beyond the second year of college. Paris Junior College also offers a number of non credit "continuing education" courses to those persons who want additional knowledge about a particular subject, but who do not want college credit.

Three two-semester chemistry courses are offered to students attending Paris Junior College.

General inorganic chemistry is designed for students who plan to jamor or minor in science, engineering, mathematics, medicine or medical science. Among the topics presented are atomic structure and bonding, symbols, formulas and equations, states of matter, acid-base theory, equilibrium, reaction rates, elementary thermodynamics, solution equilibria, electrochemistry, chemistry of the representative elements and nuclear chemistry. In the laboratory analytical experiments involving optical and electrical measurements as well as quantitative gravimetric and volumetric techniques are provided.

Organic chemistry is designed to present present day theories and principles of organic chemistry. Areas stressed include nomenclature of the main classes of compounds, the determination of structure, sterochemistry, resonance, molecular orbital methods of chemical bonding, reaction mechanisms and techniques or organic synthesis, carbohydrates, fats, amino acids, heterocyclics, alkaloids, and natural products. The laboratory emphasis is on organic synthesis and qualitative analysis.

The third course offered in chemistry is general chemistry. It is designed for the liberal arts and agriculture students. Areas of study within the course include the nature of atoms and molecules, chemical nomenclature, properties of gases, liquids and solids; the nature of acids, bases and salts; the study of selected elements and their compounds, the hydrocarbons and their derivatives, the chemistry of foods, fats, soaps, fabrics and medicines and radiochemistry. In addition topics of student interest are discussed.

This past year the general chemistry class was composed of about seventy per cent agriculture majors. It was our decision to stress a more detailed study on water purification and pesticide chemistry for these students.

The water purification section of study not only covered methods of purifying drinking water, but also methods of purifying "polluted" waste water. Topics discussed in this section included fluoridation of drinking water, removal of solid organic and inorganic wastes, removal of organic and inorganic phosphates by precipitation and electrodialysis and reverse osmosis as a future means of purifying water.

The pesticide section concentrated primarily on DDT. Such things as insect resistance to DDT, up-the-food-chain concentration of DDT, DDT's effect on the calcium metabolism in birds, and DDT's lack of fast biodegradability were discussed. Other insect control methods such as the use of insect sex attractant "traps" and sterilization of the male of the species by radiation were also discussed.

The student's laboratory experiences in general chemistry are unique in Texas. At Paris Junior College Hubert Alyea's Armchair Chemistry is used as the laboratory manual. The method developed by Dr. Alyea enables each student in the same classroom at the same time to perform "micro" experiments in distillation, filtration, electroplating and analysis. Dr. Alyea's method is not only enjoyable but also very understandable by a majority of these non-science majors.

Chemistry for Non-Science Students

Chemistry, Man and Society: A Look at Chemistry for the Non-Science Major

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Presented at the General Session of the Thirty-Third Two-Year College Chemistry Conference, Dallas, Texas, April 7, 1973.

I appreciate this opportunity to share with you some of my ideas relative to college chemistry for the liberal arts students. Let me express my gratitude to John Vondeling and the W.B. Saunders Company who have expressed confidence in my ideas. I must say my ideas are not clearly discernable, even in my own mind, from those of my co-authors: Professors Jones, Johnston, and Wood. Anything that we might say as a group or individually can only be considered as some slight modification of what has been previously expressed. It is axiomatic, that all of us sit on the shoulders of giants as we try to make out contributions. I have only four points that I want to make.

POINT I - Human survival on this planet depends at least to some extent on chemical choice!

Chemical decisions have to be made! Man is becoming more powerful in a number of ways; he now has the ability to rearrange the materials of nature into a mixture that is completely incompatible with human life. It might be possible to rearrange this mixture into a situation that is even more favorable to human life.

The mixture of nature confounded the chemist for thousands of years until he learned well his separation techniques; but it was a good mixture. Nature, as man found it was not Eden, but who will say it was less than "good". I love at evening time to look over the hills, lakes, and the valleys of middle Tennessee, and to wonder about the processes that brought this thing to its present state. The phosphorus is there in the ground under my feet . It is no problem there, but if it is extracted and thoughtlessly spread elsewhere in the environment, it could be one whale of a problem.

But the phosphorus will come out! It will come out because man has the know how to get it out, he has the power to get it out, and furthermore he has the desire for it to do a job for him, and he has the confidence that he can by doing that job make his plight better.

The question is not now whether we are going to have massive chemical change; but rather who is going to control that change and what direction it is going to take. Is there anyone who will trust the conscience of the profit makers? I'll not call them profiteers at this point. Can we trust these massive chemical changes to them? Most would say not. Is there anyone who would trust the bureaucrats, regardless of which side of the political fence they might be on to sit in their offices and exercise great wisdom and to make the decisions about the chemical future of this world? Most people are skeptical at best to trust any subgroup. Whom then can you trust to continue the future of this planet?

Winston Churchill said that democracy was the worst kind of government he could think of until he tried to think of one better. In other words, the most trustworthy decision maker is the mass of common men, acting with common sense over common concerns. Because of the cumbersome aspects of group decision making, the mass will gladly defer to its representatives as long as they elect to carry out the will of the masses. The mass will even defer, sometimes because of its insensitivity, to their representatives when they don't do the will of the mass, but only for a while. But the day of reckoning has, does, and will come in great issues in human affairs. Real sociological leadership then, is not the ability of the politician to speak with two tongues; to try to humor the masses on the one hand and then go to the seat of the government and to pass laws which will then take care of those people; it is rather to educate the masses to what the situation really is, what are the major decisions to be made, and what the consequences of those decisions are.

This brings us to liberal arts chemistry. The classical student of the arts learned for the love of learning. But the power of learning and knowledge has so greatly increased in our time that the arts and sciences have taken a more practical turn. In ever increasing numbers our students want to study material relative to their problems and to the problems of the community as a whole. The spreading of cadmium or mercury in the environment, or the thought of controlling the genetic code in the laboratory are equally staggering. The masses must become chemically aware. The liberal arts chemistry course is a step in that direction. If done well, it will be augmented by the popular media as well as a whole new approach to elementary and high school education. A chemical awareness will filter down to the masses, and they in turn will bring pressure, in whatever ways are open to them for sensible decisions that will serve the group as a whole. I know that many intelligent people will differ with this proposition: "the whole of society is to have the final trust," but I am proceeding on the assumption that this is true.

POINT II - There is ample reason to hope

I can be very optimistic. Human responsibility and cooperation may at times seem hopeless. Such is not the case for many reasons. I would appeal only obliquely to a social conscienceness that can be heard daily around the world, a conscienceness spoken in behalf of the poor, oppressed, and underpriviledged. But I would speak of matters more chemical here today.

The first six-tenths of this century left us with overwhelming problems in air pollution, water pollution, and the population. Well we have turned the corner on air pollution. Eighty-two cities of the United States have actually shown a decrease in air pollution since 1968. The problem is by no means solved, but we know how to solve it. Our society is now seeking to assess the costs of clean air and the only real question is a timetable and the degree of purity we want to pay for. Can anyone really doubt that the common man will ask for and do his best to bet a margin of safety in clean air?

Apparently, we have solved the problem of population in the United States. The birth rate per woman, per life is now 2.08 down from 2.46 in 1968. This is lower than the 2.2 figures of the depression years. It is encouraging to me to note, in the face of hysterical suggestions by some to regulate by law the number of children, or to even to sterilize certain elements within our society, the citizenry, when given the power to control and the information exercised common sense. I can only attribute this to mass education, education that helps a man to understand the hurt when he produces human life he cannot support and maintain. It is axiomatic that there can be no conflict between millions of persons solving their problems and the masses of people solving a sociological problem. The masses made the correct decision when advised by the specialists who simply gave them the facts. Can this approach work on a world-wide bases? I think it can, it depends on education; it depends on the likes of you and me, and depends on the mass media beyond us.

We are a few years away from turning the corner on water pollution. But the situation is getting worse at a less rapid rate. There is even hope now for Lake Erie.

The solutions to some of the other problems are not so immediate or so obvious. The control of the chemicals in pesticides and fertilizers is not clearly defined as yet and the full import on that problem is not yet fully understood. What are we going to do with our chemical wastes? What are we going to do about some of the resources such as Pt, Ag, Au, Al and other such commonly used metals that will be depleted as far as we can tell in 50 years or less. We have scarcely begun to learn to recycle our resources that are in short supply. The mass ignorance about foods and drugs is gross. Consumer buying is still dominated by Madison Avenue, but at some point is bound to be more and more dominated by consumer chemistry. These problems can yield and I believe they will.

The common denominator of all of these problems is the energy problem. If energy is abundantly cheap in the employ of man, recycling and purification of systems after we use them will be relatively an easy problem. And the energy is there if we can just learn how to tap it. The sun's energy gift, one calorie per square centimeter per minute on the surface of the earth, is probably all the energy that we need for a four billion person earth.

Mike McCormack, Chairman of the House Subcommittee on Energy was "telling it like it is" in his guest editorial in the April 2 issue of Chemical and Engineering News. The energy problem that we are looking at in this decade is nothing compared to the energy problem that we are going to be looking at fifty years hence. This to me is a healthy demonstration of science communication.

We have the information feeding from a portion of the scientific community to the educated elite, with feed-back to the greater scientific community, and then a filtering down process so the entire mass of the American people can understand what is involved. The hope for tapping the available energy is real, but the consequences of such a massive energy flow on our environment are not yet clearly understood. But breakthroughs can be made and people can understand the importance of these breakthroughs and our pathway can go toward that which is better.

Perhaps the most hopeful sign of all is that scientists and science educators are awakening as never before to their moral obligation that goes along with their science. It is not enough to do the science or to know the science; you have to have an understanding of the interrelationship of this knowledge with the human endeavor and the impact that you personally are having upon it.

As an example, W.T. Lippincott, editorially calls in the Journal of Chemical Education for scientists who teach science students to give high priority to the moral and ethical values. He says it is our job to get science majors to appreciate the immense impact of chemical science on human activity and the considerable responsibility of chemists to continue to make this kind of contribution. These voices are bound to be heard and their influence will filter down and have a positive effect on the interface of our discipline and society. If we do not, the quote from Alan C. Nixon, President of ACS, is apt:

> "The citizenry has been demanding that the sacred cow of science be milked for more technological benefits or no more hay."

Surely then the answer is, in part, more and better emphasis on effective communication in chemical education. We might admire Napier, the discoverer of logarithms, but I doubt that we can sympathize with him when he discovered a powerful explosive one time and he tried to keep it in secret in order to protect the people. We can take no comfort at all in ignorance.

POINT III - Hope is in education, not training

Educators have not displayed generally, in the product they have produced, always a clear distinction between education and training. As Robert L. Wolke, of the University of Pittsburgh recently wrote, "We have gone much too far in just behavioral objectives." To solve problems that have already been solved is not the goal of education; that is training. To be sure, you can't have education without training, but it is certainly true that you can have training without very much education.

The reproduction of professorial notes, the solution to the number problem in ionic equilibria, the memorization of a selected set of facts-- all training just as surely as the baseball training camp. The great pity of it is that too many of our students never get past the training. And I am afraid some of us as teachers sometimes think only in terms of those training exercises. How often have you and I both looked back into the eyes of that student who wanted the problem set-up more than he wanted the problem? Sometimes I get so tired I just give him the problem set up.

To be able, from the past experiences of man, to think new thoughts, to solve new problems, to advance the human cause, and to develop the brotherhood of man -- this is education. In this framework we can understand the cry for a new theorem, a new compound, a new expression of art or a new choice of words to help articulate the expanding thoughts and feelings of humankind. These desires have their richest fulfillment when that which is new solves or partially solves an existing human problem. The Christian doctrine teaches that man is in the likeness of his God. The qualities of the Christian God are creativity, love of the created, and power to control the created environment. Now we may or may not be adherents to the Christian faith. We may argue that society drew its values from the religion or that the religion drew from and evolved from the morals of man. But one thing is sure: Man does have a drive toward creativity, he wants desperately to care and be cared for, and he wants to have a measure of control over his environment and his destiny. This is the process of education in its fullest measure.

Alfred North Whitehead has said it another way and probably much better in his book entitled "The Aims of Education". He said that there are three stages to education: the stage of romance, the stage of precision, and the stage of generalization. The stage of romance is the stage of first appreciation. There is the sheer joy of soaking up the material, usually the easier and more glamorous aspects of it of course, with no thought of systematic study or organization. The appreciation of music or the fascination with chemical change. I shall never forget when my sister came home from college and mixed up vinegar and baking powder. I have been interested in it ever since. Then comes the stage of precision; this is a period of mental training. The experiences are mastered, at least a large number of them, and the organization is structured to give substance to the framework. It is not new thinking, but it is certainly the base for new thinking. The scoring of music or the rationale for chemical change is mastered. Then comes the stage of generalization; the whole of it all is made to work. The new problem is approached, measured, and mastered as a logical extension of the previous framework built. This is the most joyful part of all, more than the stage of romance and certainly more than the stage of precision. The symphony is written; the molecule has been structured so that the drug can cure the disease.

We tend to go to extremes. For years the college chemistry curriculum forgot the romance and few survived the precision, so intensively given, to get to the plateau of generalization. What hope was there for the liberal arts student denied of any of the romance, and with no real possibility of getting to the point of generalization? He just withdrew.

Then a slow but sure awareness began to grow in the college community and in the society as a whole. It was reflected in the age of sputnik and in the prep school science programs that the liberal arts student and society at large could not afford to withdraw. Its vital self interest was at stake. But what do you teach a liberal arts student of chemistry? How about a programmed study of facts? Hardly. Is there any real hope that he can reach the stage of generalization of a chemist? No. But that is not really what he is after. But what he can do with his liberal arts education is to generalize about what the science is, how it began, how it has grown, what it is presently capable of doing, and how it interacts with society as a whole. He will not be able, nor does he want the chemist's chemistry; but he wants to have a grasp of the import of the science. He then, because of his detachment from the science and thousands more like him, might be in a better position to look over our shoulders and grapple with some of the great decisions of our time that are basically chemical in nature.

The chemist, if he has as much sense as I think he has, will not take a condescending view to the liberal arts students. We have just been through a period, and are still in it to some extent, in which we give the liberal arts students just a large dose of romantic chemistry. "It matters not what you teach them, just have a ball, and they will think chemistry is groovy." This is tempting and it will flourish for awhile, but it will not satisfy. We as chemical educators must approach the liberal arts students with the goal in mind; the educated student must have a grasp of the science of chemistry, what it is, what it is about, and what it is doing,and generalize at the interface between this science and our culture.

POINT IV - The Natural World Probably Can Be Improved

As I look again over the beautiful Tennessee countryside, I have a strong tendency to say, "Let it alone!" But this is not reasonable for we could have no more than a few million people in the world. How could we willfully go back there? We now live rather far from the hard clash of the individual with nature in order to get food, clothing and shelter. Those who were there wanted change, so there is no going back. Therefore, the phosphate must come out of Tennessee.

But how and on what basis will nature lend its wealth and strength to the will of man? This is our place in history, we chemical educators now have the opportunity and the responsibility (by all that is good, holy and sacred) to point out the facts, examine the options, project the reasonable consequences of our choices, avoid the temptation to play God and act as though we know the future, help to educate the elite and through them the masses, and hope for the rationality and the sensibility of common man.

Of course it is a complicated process, and nobody of course knows better than I that I have probably overstated some things.

I have done this purposely in order to save your feelings a little bit. But the task is obvious and my hope is renewed when I realize that most of us thrill to the opportunity at hand. If not our hope, this hope in education, as per Winston Churchill, what is it?

So our survival to some extent does depend on chemical choice:

There is ample reason to hope.

Hope is in education, not training.

The natural world probably can change, will change, and probably can be changed by the likes of you and me for the better.

Thank you.

Chemistry for Allied Health Programs

Ethelreda Laughlin
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Presented as a workshop for Allied Health Programs, the Thirty Seventh Two-Year College Chemistry Conference, Monroe Community College, Rochester, N.Y., October 12, 1973.

The workshop was concerned with two laboratory experiences in Biochemistry. One was making a DNA model according to the directions given in *Molecules, Measurements, Meanings, A Laboratory Manual in Biochemistry* by David W. Krogmann, W.H. Freeman Co., San Francisco (1971), Experiment 13, Nucleic Acids, The Basis of Biochemical Identity, pages 69-73. Only the Double Helix on pages 71-73 was reviewed.

The directions were modified slightly. Two four-liter graduates were used for the template. A 50 inch length of string was spiraled clockwise, and evenly spaced, from the top to the bottom of the graduate and held in place while masking tape (about 1/2 inch width) is pasted over the string. Cross-markings are then made on the tape at intervals of 5/3 inches. Two strands of insulated wire (two different colors) are then laid on the tape,one at a time. The wire must be coiled clockwise (as for righthanded screw threading) to make an alpha helix, not a beta helix. The wire is marked like the masking tape at 5/3 inch intervals with wax pencil.

Next, 30 pieces of small copper wire (12 gauge), cut into six-inch lengths are attached from one strand of the helix to the other. It helps if the wire ends are wrapped around a pencil to form a half circle at each end and then crimped to the helices with pliers at the wax pencil marks. One helix should be laid on the desk and the second inserted so that it is antiparallel to the first. Start with the first cross link and work down being careful not to miss any.

Base pairs, on colored paper, are then attached to the cross pieces with scotch tape.

The attached photograph, although a Beta helix (not alpha as it should be) shows the final structure.

The second experiment is one produced by Purdue University. It's Protein Synthesis. The script was written by Thomas Luce and may be obtained from Purdue. The student handouts are purchased for sale to the students. The script was put on tape and played to the audience. In class, an individual student would listen via head phones.

A packet must be purchased from Freeman Company to accompany the handout and tape. It's a packet by Thomas Peter Bennett called Elements of Protein Synthesis, An Instructional Model.

Both exercises have been successful in paramedical chemistry programs at Cuyahoga Community College, Western Campus.

Chemistry for the Allied Health Science - A New Look

George Sackheim
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Chicago, Illinois

Presented at a Concurrent Section, the Thirty Sixth Two-Year College Chemistry Conference, the Loop College of the Chicago Colleges, Chicago, Illinois August 25, 1973.

Perhaps this paper should be called "How to become more than just a chemistry teacher in today's changing educational world". This area of chemistry has undergone much change recently, particularly in the emphasis on direct application. Many tedious laboratory procedures are no longer performed, but are replaced by machines. Meaning of results and action to be taken are now emphasized. In addition, students must be shown that chemistry is not an isolated subject. Examples of the relevance of some areas included:

1. Metric System: Medication in terms of mg per kg of body weight or heat loss per square cm of body area.
2. Elements: Function of trace elements, which elements and why are poisonous
3. Rates of reaction: Rates when body has a high fever.
4. Energy: Chemistry of ATP, cyclic AMP, enzyme activity.
5. Diffusion and osmosis: Hemodialysis, isotonic solutions.
6. Gas Laws: Partial pressure of O_2 and CO_2 in blood, etc.
7. Redox: In terms of loss or gain of oxygen or hydrogen in body processes and electron donors in the mitochondria
8. Radioactivity: Many uses in medicine, many misconceptions regarding residual radiation in table after

x-rays or cobalt treatment.

9. Electrolytes: Importance in metabolism and fluids, pH, concentration of sodium in extracellular fluid and potassium in intracellular fluid accounting for the presence of sodium and potassium buffers in those fluids

10. Drugs: Not enough to just mention them; what about structure related to specific reactions, incompatability of drugs (even CCl_4 inhalation after several drinks of alcohol can lead to death quickly), LSD breaks chromosomes with subsequent genetic damage and to a lesser degree so does caffeine.

11. Pollution: Discussion could certainly lead to contamination of foods, medicines, incisions, etc.

12. Research: Include relevant material such as the latest information that we now know aspirin works by inhibiting synthesis of prosaglandins.

As the biology teachers must include considerable chemistry, so should chemistry teachers include relevant material from biology. This will make chemistry one of the most integrated of the sciences.

Questions and comments following the report:

Could you suggest up to date reference books at a level higher than what we will be teaching that will give us the background in courses, such as biology and physiology, which are necessary to teach the biochemistry and physiological chemistry.

A possible solution is workshops with biology and chemistry teachers together. No list of references is readily available, but there are many new biochemistry books. I can't think of any one in particular right now. Actually, most of them are too complex.

What can be done about teaching the practical applications to the students. Whose responsibility is it?

You mention it to the students and refer to the fact that it may be more thoroughly explained later in either this course or some other course.

How much of a course should be practical and how much should be conceptual. Practical applications are good in pure groups, but in mixed groups it becomes a problem of risking alienation by citing applicable to a specific profession.

You must try to strike a balance. The real test of teaching ability is being an interdisciplinarian in teaching the practical applications.

The function of the teacher is that he tells himself what he is going to teach. He must adapt to the situation and conditions.

Chemistry and Civilization

Kenneth Kolb
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Presented to the symposium on Innovations in Teaching Chemistry, Environmental Science, and Environmental Technology related to Chemistry, Thirty Sixth Two-Year College Chemistry Conference, the Loop College of the Chicago City Colleges, Chicago, Illinois, August 24, 1973.

Chemistry and Civilization is a course offered to juniors and seniors, who are non-science majors. The course is a three semester hour, non lab effort to reach some of the majority of the students at the university who are not science majors.

Every effort is made to provide an interesting course, including the first class starting with the carbide cannon and the taking of a flower, extracting the pigment and demonstrating that it is an acid-base indicator. Many of the students have no background in chemistry.

At present the course is divided into thirds. The first third includes what might be called conventional background with frequent demonstrations including discharge tubes leading to the Bohr atom and to spectroscopy.

The second third is organic chemistry and includes the Bielstein test for halogens and the story or combustion.

The last third is unconventional and is presented in modules. Modules have included petroleum, energy, pollution, halogens and insecticides, left and right handed molecules, lipids, steroids and the Pill, glass, sand and imagination.

The teaching methodology used is one of simultaneous team teaching. Two instructors in the room at the same time and sometimes talking at the same time. Guest lecturers, daily squibs (from magazines and newspapers), audio tapes (short ones such as exerpts from Man and Molecules), slides, a few movies and other techniques are among the means of instruction employed. Several units that have been found to be of interest have been packaged as modules and some of the selection is available.

Evaluation is done through four multiple choice examinations, covering principles, facts and reasoning. There is no term paper. The enrollment has grown to four sections with an average section having 54 students.

Questions and comments following the report:

Does the course include laboratory?
No, it is a lecture - discussion course only.

Comment: There has been a follow up mini course using book. The chemistry majors shouldn't be forgotten when it comes to interesting aspects of chemistry.

Chemistry & Mankind: Revolutionary Chemistry at the Univ. of Wisconsin

Elizabeth Kean
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Madison, Wisconsin

Presented to the symposium on Ecological and Environmental Approaches to Teaching Chemistry, Thirty Sixth Two-Year College Chemistry Conference, the Loop College of the Chicago City Colleges, Chicago, Illinois, August 24, 1973.

Chemistry 107, Chemistry for Mankind, has evolved as a one semester terminal course for non-majors at the University of Wisconsin. For most students it is not required and has none of the constraints of being a prerequisite for any other course. The course is intended as a chemistry course and not a course "about" chemistry. Approximately half the semester is devoted to basic chemistry and the second half to applied chemistry. It was intended, that is the basic philosophy of the course, to keep the sense of wonder and remove the aura of the occult that seems to keep many students from exploring the world of science. To enable the student to more effectively cope with technological society the course centers around those aspects of chemistry which most effect people- nuclear chemistry, organic chemistry and biochemistry. Nearly half the course is devoted to background information so that students can speak the language. Suggestions are solicited from the students for topics to be discussed in part of the course.

The current school year the following topics are included with the approximate time alloted:

A. Nuclear Chemistry (4 weeks)
  - Discovery of Radioactivity
  - Alpha, Beta and Gamma processes
  - Decay laws
  - Detection
  - Natural and Artificial
  - Nuclear Energy

B. Organic Chemistry (7 weeks)
  - Electron Structure and Bonding
  - Atomic Orbitals and Hybridization
  - Molecular Orbitals
  - Nomenclature and Structure (Hydrocarbons, alcohols, ethers, carbonyls, nitrogen and phosphorus)
  - Isomerism
  - Processes of Substitution, Addition, Chain reactions

C. Biochemistry (4 weeks)
  - Fats and Oils
  - Carbohydrates and Metabolism
  - Energy Production
  - Amino Acids, Protein and Synthesis
  - Purines
  - Nucleic Acids
  - Steriod Hormones

In each main group topics of interest to the students are discussed; such as nuclear reactors and weapons, petroleum chemistry and politics, pesticides, polymers, pollution, contraception, euthanasia, etc.

The format of the course includes three lectures per week, with one of these frequently being from a guest lecturer and two deal with information transfer. Sizes of the lecture will be kept at 75 so at least there is a possibility of two way communication to a small extent. Lecture material will be available either on video tape or in handouts so that students come willing to listen, think and question, rather than "take notes like mad". It is hoped that eventually auto-tutorial materials with behavioral objectives can be prepared. In addition to the lectures the students meet with a graduate teaching assistant an additional five hours per week in groups of 21 or less. Three of those five hours are in laboratory and the other two in small group discussions. The lab consists of students doing six experiments dealing with environmental systems; water hardness, glucose in blood, etc. In the small group sessions a great deal of student learning takes place. There is no set format for these sessions and discussions may center about drill of factual material, lab experiments, text material or reprints from Science, Scientific American, etc.

The instructors attempt not to indoctrinate students with their personal biases but are free to express their feeling, beliefs and opinions as participants in the group and not as authorities.

Evaluation of students' level of learning on the chemical aspects is rather straight forward and the grade is based on completion of problem sets, laboratory reports, an optional term paper and an optional final exam. The students contract for grades. If most (8/10) problems sets and lab reports are done a C grade is available; all problem sets B-C, extra work A-B, term paper A. No attempt is made to grade on the growth in attitude of the student although this is a main objective of the course.

Evaluation of the course and instructors by the students is sought.

Comments and Questions following the report:

How are students selected?

At first they were preselected (honors type), but now the course is open to anyone. Mostly freshmen take the course and it was found that 80% were pre-business. It has a prerequisite of high school chemistry.

Is the lab scheduled or open?

Scheduled.

I find it hard to understand how you can avoid moralizing.

Instructors try to hold off comments until students express their ideas. They they do not try to hide their bias, but don't try to force students to accept their views.

Chemical Technology

Relevance in Science Laboratory Technology Programs

Stanley M. Cherim
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Media, Pennsylvania

Presented to the General Session, the Thirty Seventh Two-Year College Chemistry Conference, Monroe Community College, Rochester, N.Y., October 13, 1973.

When talking about laboratory technology programs, the term relevancy would seem almost to be redundant. (In theory anyway) But self-evident relevancy is not necessarily true. The gap between the giving of lipservice to the concept of relevancy and the realization of relevancy must be thoughtfully bridged. This can be done by the instructor setting the tone, or in other words, creating the proper intellectual atmosphere right at the beginning of the course. Then constructing a course that employs texts and materials that are oriented toward research and industrial laboratories rather than educational laboratories, would be the second step. The difference is often enormous. Finally, by means of field trips or preferably, part time employment in cooperating local scientific industries, the transition from classroom to job can be smoothly effected.

In setting the tone I usually tell my students about an actual happening while I was working for a large pharmaceutical company. A young woman graduate of a major university came to work as a biochemist. Her credentials were excellent - chemistry major and an "A" average. She was fired in less than two weeks. The tragedy was that while her mastery of theory was obvious, her laboratory experience at the university left her shockingly unfit to function in a research laboratory. Her manual dexterity was undeveloped with regard to apparatus. She had no meaningful concept of precision and accuracy, and her attitude toward property and living experimental animals was unbelievably cavalier. In short, she was a plague and a disaster in the research program.

My students quickly grasp the message. I cannot, as a morally responsible teacher, permit this kind of atmosphere to exist. The place for joking, horseplay, and general socializing is not in the laboratory. In the training of laboratory technicians we must be concerned with developing a sense of professionalism and growth in self-esteem. This is not easily compatible with a happy-go-lucky attitude. We must impress our students with the possible hazards associated with a laboratory and with the grave responsibility they may have in so far as they become involved in experimental programs dealing with the health and well-being of people. They should not be above demonstrating a respect for life in general when working with experimental animals. We can talk about dignity, self-respect, commitment, and other human values, but to no advantage unless we establish a climate in which these values can flourish.

In another vein, I see relevancy in Lab-tech programs becoming a reality if we insist on maintaining contacts with recent developments in research techniques and instrumentation. And if we are willing to risk an uncompromising "hands on" approach to all types of apparatus and instrumentation. And finally, if the expectations we hold for our students are realistic.

Considering realistic expectations, I submit that a bachelor's degree including majors level general, organic, and physical chemistry for a laboratory technician does not fit. Such curricula are self-defeating because students who are able to cope with high level science courses will understandably abandon technician aspirations in favor of Ph.D. goals. The fact that our society has been traditionally unrealistic in this respect has caused us to produce a number of second-rate researchers (sometimes bearing impressive credentials) who could have been outstanding technicians. It is encouraging to observe a trend however, toward the evaluation of a person on the basis of performance rather than degrees and titles.

Realistically, for most of our aspiring technicians, we need to start at the beginning. Develop the basic skills and labor patiently until there is a sure grasp of basic scientific concepts.

The intellectual skills should start with basic mathematics and include: scientific notation, significant figures, construction and interpretation of graphs, units of measurements (SI) for linear dimensions, volume, mass and energy. The use of conversion factor techniques and dimensional analysis should be stressed. Include basic electrical units and relate them directly to practical application. Other skills to be developed would be in the area of formulas, nomenclature, equations, stoichiometry, solutions, gases, acids and bases, equilibria, oxidation-reduction, electrochemistry, organic chemistry, biochemistry, nucleonics, the "what" and "how" of instrumentation, and in general, techniques of systematic problem solving so that the natural powers of inductive and deductive reasoning can be profitably harnessed. Add to these skills: technical writing, report writing, record keeping, library searching and oral communications facility.

The practical skills (or call them the laboratory skills) should include many gravimetric and volumetric determinations. The sensible selection and use of all common types of glassware and hardware should not be omitted. Methods of sampling, uses of controls, preparation of solutions, titrations, and error analysis are necessary. A most important aspect of modern laboratory activity deals with the awesome array of instruments; spectrophotometers (vis. UV, IR, split beam, double beam, fluoresence), gas chromatographs, atomic absorption, mass spec., NMR, refractometers, melting point and high speed centrifugation, among others.

In a traditional chemistry course, relevancy is currently in vogue. Nevertheless it is still optional. The correlation, if not the integration, of laboratory work with lecture topics is a matter of choice. But there really can be no option in technology programs if they are to be of any lasting value to the students. If there is no possibility for an apprenticeship in an industrial lab, we have no choice but to try to imitate the real thing. Our laboratory technology programs will be attractive and stimulating to students and serve their needs only to the extent that our programs are truly relevant.

Chemical Technology at Oakton Community college

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Presented to a Concurrent Section Meeting, the Thirty Sixth Two-Year College Chemistry Conference, the Loop College of the Chicago City Colleges, Chicago, Illinois, August 25, 1973.

In this day of technology in all areas, there is also a distinction between a chemist and a chemical technician and the college programs offered should also bear this in mind. A watered down baccalaureate program for two years is not the way to go nor is it logical to expect a technician to follow the baccalaureate program for two years and then quit. The technician should be primarily concerned with the laboratory skills, while the chemistry courses for future B.S. chemists should emphasize theory as well as laboratory skills.

The program at Oakton was designed with the above distinctions in mind. We did not simply pick from already existing courses in chemistry, physics, math, etc. Thirteen courses were designed including seven chemistry courses, four of which are based on the ACS texts, Modern Chemical Technology. These four have two hours of lectures and six hours of laboratory each. The other three chemistry courses are called Lab Skills I, II, III.

Lab Skills I	2 hrs. lecture, 3 hrs. lab Machine shop, plumbing, plastics, refractories and insulation, furnaces and ovens, corrosion, purification of water, mixing and sieving, and glass blowing.
Lab Skills II	2 hrs. lecture, 3 hrs. lab Drying, crystallization, melting and boiling, flow meters, care and cleaning of it, Rh, etc., and introduction to chemical microscopy.

Lab Skills III	2 hrs. lecture, 6 hrs. lab Unit Operations: Fluid flow, Mass transfer, filtration, distillation, heat transfer, Industrial Microbiology: Techniques in microbiology labs, methodology, sampling, personal hygiene, plant sanitation and animal handling.
Industrial Safety	2 hrs. lecture First aid, hazardous materials, lab safety equipment.
Technical Physics I and II	3 hrs. lecture, 3 hrs. lab Metric system, temperature measurement, mechanics, color, light, optics, electricity, magnetism, vaccuum technology, pressure technology, radio chemistry
Math Skills	3 hrs. lecture, 3 hrs. lab Common and natural logs, slide rule, desk calculator, data processing, programmable calculator, statistics and graphing
Seminar	2 hrs. Catalogues, ordering, patents, company representatives, job hunting
Technical Communications I and II	3 hrs. Grammar, sentences, reports, photography, AV equipment, engineering drawing, public speaking, library

The program was started at Oakton in September 1972 with 8 students of whom 4 are returning and 13 beginning students in September 1973. If more information is wanted, contact Dr. Jaffe at Oakton Community College.

Chemically Relevant Math for Technology Students

Ishwar Singh
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Presented at the symposium on Innovations in Teaching Chemistry, the Thirty Seventh Two-Year College Chemistry Conference, Monroe Community College, Rochester, N.Y., October 12, 1973.

This paper describes the contents of the computer applied mathematics course offered to the third year students in chemical technology program at Mohawk College. In the first two years, after grade 12 from an Ontario high school, of their stay here the students have had the following topics; college algebra, geometry, trigonometry, calculus, nomography and a brief introduction to FORTRAN programming.

The three main objectives to be met for this course are:

(a) to enable the students to reduce and analyze routine data, with and without the aid of a computer, from an industrial and research laboratory

(b) the course must be relevant

(c) the student should be able to apply the methods learned in this course to others, in order to increase their effectiveness and relevancy.

To accomplish these objectives, the choice of the following topics along with approximate number of classroom periods spent on each of these is adhered to:

TOPIC	PERIODS
Computers	4
Hewlett-Packard	4
FORTRAN IV	20
Numerical Methods	6
Solution of equations	
Integration	5
Interpolation	4
Differentiation	2
Matrices	12
Accuracy, Number System	4
Regression Analysis	14
Optimization	10
Differential equations	6

Each student attempts seven computer related individualized projects, in addition to writing four tests on topics not covered by these, over a period of two semesters. The texts used for this course are (a) a set of notes compiled by this author (b) FORTRAN IV manual for IBM 360 and 370 systems (c) Hewlett-Packard manual produced by Mathematics department.

COMPUTERS AND PROGRAMMING

The discussion related to the importance and type of computers used by chemists is a good starting topic. The fact that by 1980 the Canadians will be spending 5% gross national product on computers and rapid acceptance of computers by the chemical industry [2] brings to light the importance of this topic. A few of the examples of computer aided and controlled instrumentation such as AUTO C, H, N and O[3], gas-chromatography[4,5], Auto-chemist[3], and x-ray diffractometer[6], are presented using their block diagrams and slides. The computing facilities at the college, which include IBM/360, supported by disk operating system, Sigma 7 & IBM 7094 through remote time-sharing terminal Hewlett-Packard, series 9100 A & B with a plotter, PDP-8, 11 and 12 Series, ANOVA, and about a dozen small desk calculators. Next programming language for the Hewlett-Packard (HP) desk top computer, using overlay transparencies which increase the effectiveness and decrease the time of presentation of the topic is introduced. These four lectures are enough to start the students writing simple programs using HP language. A good understanding of HP language helps many students to understand FORTRAN IV language faster than without exposure to it. The following simple programs are made available to the students to carry out routine calculations in their other courses and some of these are discussed in the classroom as relevant examples: spectrophotometric error, Nernst equation, least squares fit to a straight line, first derivative or gran function for titration calculations, and plotting a polynomial. This last program is used regularly with regression analysis problems discussed later in this course.

The FORTRAN IV programming language, using gas-equation problems to introduce the input-output and arithmetic statements, is considered next. The use of DO loops, subscripted variables, sub-programs IF and GO TO statements are shown by the example of a computer program to calculate the titration calculations (involving the printing of first derivative, second derivative, gran function, for a potentiometric or spectrophotometric data requiring the location of inflexion point), and with another example of curve fitting with statistical analysis for spectrophotometric calibration data program. These two programs along with the following general purpose programs (a) for finding the root of an equation by bisection method (b) statistical calculations for a radiochemical experiment (c) linear interpolation, are either stored on the disk in the computer center for ready use or the card decks are made available to students for their regular use in other courses.

NUMERICAL METHODS

The general approach in presenting this topic is to give first a brief background of the method, a specific alogrithm, and a discussion of a computer program. The derivation of various formulae given is not attempted, rather the emphasis is on their use in problems along with any limitations of the numerical alogrithm. The first topic in this series is the graphical, linear iterative, and Newton-Raphson method of finding the roots of polynomial, transcendental and algebraic functions. The three simple examples from the field of equilibrium concentrations, ionization constants and solubility of compounds like CaF_2 in the presence of other ions,[11] are solvable by these methods. The convergence formulae and limitations of each method are presented to offer guidelines for selecting a suitable method. Next a FORTRAN IV program calculating the equilibrium, concentrations of various species in an aqueous solution of phosphoric acid using Newton-Raphson method is discussed. A FORTRAN routine from IBM SSP to find the real and complex roots of a real polynomial is stored on the disk for the ready use by the students. This routine is used later on by the students to find the predicted values of the independent variable from a polynomial calibration curve, given the observed value of the dependent variable.

The next three methods are based on the determination of a polynomial equation to approximate either a data given in the tabular form or an analytical function and then using this approximated polynomial in interpolation for predictive uses, to numerically integrate and differentiate the tabular data or the analytical function. Newton's method for equal intervals of the independent variable and Lagrange's method, for unequal intervals, of interpolating polynomial is presented with examples from elementary chemical engineering. Other methods of data smoothing like Fourier series method and spline fit are briefly mentioned. Numerical integration techniques using graphical method, trapazoidal rule, Simpson's rule, Monte Carló method, and Gaussian two to five point formulae are presented. This is a good point to consider, the use of single and double precision arithmetic and its effect on the computation using the above methods. In addition, a comparison of different methods with regard to their efficiency and the effect of round off errors is also considered. Integration of peaks from gas chromatography, S from C_p vs T data and black body radiation problems are some of the examples briefly mentioned, with a detailed discussion of computer program to calculate theoretical heat capacity of solids using the trapazoidal rule. In conjunction with Monte Carlo methods, various sub-routines for generating random numbers are provided and students use these in one of their projects for simulation of experimental data.

Matrix algebra[1] is one of the most applied numerical methods to many chemically oriented problems but still many undergraduates get a minimal exposure to it. In this course first some of the basic definitions and operations such as addition subtraction, multiplication, evaluation of the determinant, rank of a matrix, and inversion are presented using only two by two or three by three matrices to minimize the strain on students. The solution of simultaneous equations using the inverse method (triangular matrices like $A^{-1} = (TT^{1})^{-1})$ (T^{-1}) is used) and Gauss elimination method is discussed, again using simple matrices. A comparison of various methods is presented to make students aware of truncation and ill-conditioning problems. The following is the list of areas which involve the application of matrices (a) multicomponent analysis by Ultraviolet-visible, Infra-red, mass spectrometry and X-ray methods (b) indipendence of chemical reactions (c) matrices and molecular vibrations[7], (d) curve fitting and function evaluation by the method of least squares. Applications in optimization and regression analysis are considered in the next two topics. At this stage students are introduced to the use of time sharing terminal and use of MAT instructions in BASIC language to analyze the multi component mixtures by the method of matrices. I also show them calculations using Hilbert matrix ($a_{ij} = 1/(i + j-1)$, since this matrix is particularly sensitive to the problems of finite precision and ill-conditioning. A brief discussion of various subroutines from IBMSSP for matrices concludes this topic.

Regression analysis [10,16] topic, probably the most routinely used, follows the matrices in a logical manner. First it is pointed out that to determine and use a calibration curve or present any graphical data by the use of an analytical function, one must consider the following aspects; (a) choice of the model (b) method of estimation of parameters (c) standard deviations, confidence intervals and other statistics (d) distinction of model through origin from the model with blank effect (e) minimum number of observations (f) transformation of models to simple models (g) and outliers. Linear, Polynomial and Multiple regression analysis is presented in considerable depth. The matrix method of computations is emphasized because (a) it provides with a compact notation (b) this is the method most commonly used for computer programs. However, for polynomial regression problems, a comparison of results obtained using the method of orthogonal contrasts and matrices emphasized the pitfalls in various computational procedures. For this topic there is no dirth of available data for relevant presentation. Spectrophotometric, x-ray spectrographic[8] and kinetic data are some examples considered to illustrate the use of linear and polynomial calibration curves under the above aspects. For multiple regression analysis, the following problems are very suitable; (a) x-ray fluorescence data for multi-component analysis (b) -log K_d vs $\Sigma\sigma$ and Δ where K_d is the equilibrium constant of an aldehyde or ketone in water, $\Sigma\sigma^*$ is the sum of aliphatic polar substituent constants and Δ is the number of aldehydic protons[9], (c) yield of a chemical compound vs the pH and the temperature of a reaction (d) Fluorescence intensity of a metal complex vs concentration of complexing agent and pH of the solution. The last two examples are presented using coded data to perform the computation using paper and pencil alone.

Optimization methods[15] is the most useful topic not covered in many undergraduate programs. First the importance of this topic to chemists is discussed and then linear programming is introduced. The example of quantitative spectroscopy for analyzing multicomponent mixtures using LP technique is presented. It is important to point out here that such problems are also attempted using methods discussed earlier, which sometime give negative concentrations. The other examples involving fuel blending and paint mixing solved by these methods are briefly mentioned. Next a Simplex hill climbing routine for calculating the composition of a three component oil fat mixture[14] to meet a given product dilatation temperature control is presented. Viscosity vs temperature[13] data is used to illustrate the non-linear least squares method.

The last topic covered in this course is the solution of first-order ordinary differential equations. A discussion of Runga-Kutta methods is presented with an application and a computer program to handle the Kinetic data[12]. Truncation errors, stability and step size control in the Runga-Kutta Algorithms is briefly discussed.

STUDENT PROJECTS

In the first week of each semester students are given a list of projects to be completed during that semester. Each student writes two simple programs, related with chemical problems, for the HP computer. Three original FORTRAN IV programs, involving the use of DO loops, subscripted variables, GO TO and IF statements, sub-programs, random number generation routines and a numerical method with applications to chemical problems.

The various analytical chemistry journals are an excellent source for writing new computer programs. Since each student in the class attempts a different problem from the other, this method of individualized program assignments has provided this author with about 100 working programs over the past three years and in addition is ensured that each student learned the required material. In the following three areas the students attempt individualized computer generated problems: (a) curve fitting (b) interpolation (c) matrices. An average student requires about 10-12 hours of work to finish the above set of problems. In addition to the above assignments in curve fitting, students use the applications programs already stored to analyze linear, polynomial and multiple regression problems from analytical chemistry journals. They also write four short tests to cover the topics not covered by any of the above projects. At the end of the year a programmable project is expected too from each student, which is used in the next year as one of the individualized projects. A partial list of some typical programs attempted by the students is given below:

(a) Sorting of Infra-Red Spectra
(b) Stability constants from the formation constant
(c) Youden's method of analyzing data for interlaboratory studies
(d) Determination of Ionization constant equivalent weight of weak acids using potentiometric data
(e) For acid, base, or metal systems Calculation of distribution diagram, summation distribution diagrams and formation curve
(f) Comparison of various numerical integration methods using Debyes equation for heat capacity of solids
(g) Method of steepest descent to calculate the minimum value of a function.
(h) Least squares program for analyzing spectrophotometric data using straight line and line through origin.
(i) Least squares method to distinguish between data for S_N1 and S_N2 reaction.

In conclusion, it can be stated that the course is very much practical oriented and involves the learning of programming languages, numerical methods and individualized student projects.

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